Gypsum in Minoan Architecture: Exploitation, Utilisation and Weathering of a Prestige Stone

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ABSTRACT

The present research examines the use of gypsum as a building and ornamental stone in Minoan palatial architecture during New Palace period. Survey, of the outcrops and the buildings, indicates a limited distribution of architectural gypsum that is exclusively used in the finest rooms of the most outstanding Neopalatial buildings of central and east Crete, and assigns a prestige character and a symbolic significance to the material. Furthermore, the abundance of gypsum in the outcrops, in contrast to its limited systematic quarrying, suggests a controlled access to the outcrops, restricting its use to the elite of the society. A detailed examination of four thousands gypsum architectural members from Knossos, Phaistos, Agia Triada, Megaron Nirou and Pyrgos, provides insights into the provenance, the methods of production and supply, the variations and similarities in the range and popularity of forms between sites and allows the estimation of the total volume of gypsum per site and architectural function. Provenance was investigated by means of comparative petrographic study of the gypsum varieties that occur at both outcrops and archaeological sites. Examination of samples from Knossos, Phaistos, Agia Triada, Megaron Nirou, Pyrgos, Galatas, Zakros, Palaikastro, Pseira and the Neogene outcrops that are located in the region of each site indicated that the Knossian quarries supplied Megaron Nirou, Zakros, Palaikastro and Pseira, while Phaistos, Agia Triada, Galatas and Pyrgos exploited their own local sources. The predominant weathering forms that occur on Minoan gypsum were classified and described with respect to the crystallographic characteristics of the material and the factors and mechanisms of deterioration.

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CHAPTER 1

INTRODUCTION

The objective of the present research is the comprehensive study of gypsum as a building material in Minoan architecture, with an attempt to assess its archaeological and social significance. Further, the factors and the natural processes involved in its deterioration are examined with respect to its physical and chemical characteristics, taking into account the environmental exposure of the material from the Minoan era until the present.

As reflected in the architectural remains in central Crete, gypsum is selectively used by Minoan builders as a structural and ornamental stone in elite architecture, such as the palace of Knossos and its surrounding buildings, the palace of Phaistos, Agia Triada, Megaron Nirou and Archanes and Galatas. In the east it has been mainly used at Pyrgos, although small amounts of it have been found at Pseira, Palaikastro and Zakros. Small quantities of gypsum are also found in Cyclades at Akrotiri, and on the Mainland at Mycenae, and Tiryns.

Although the severe deterioration of gypsum architectural elements has long been realised by scholars who studied Minoan Crete (Evans 1928:352, 1930:287, Graham 1962:104, 144), no attempts had been made until recently to undertake an extensive study of the weathering mechanisms and the aspects of its conservation and preservation. Besides, the exploitation and utilisation of gypsum in Minoan Crete and its possible socio-political aspects have received very little attention. The existing information is scattered in archaeological reports or stone-related studies, mainly in the form of undefined annotations based on regional observations (Dermitzakis *et al.*

1990, Evans 1921-1935, Evely 1993, Graham 1962, Levi 1976, Pernier and Banti 1951, Shaw 1973, Waelkens 1992).

However, technology, trade, provenance and the use of stone in antiquity are issues that are increasingly gaining interest, as new disciplines are introduced to archaeological research. Most of the studies concern stones that were valued highly enough to be transported over long distances, or the ones that were utilised for the execution of works of high artistic and historic significance. The most extensively studied stone, in that sense, is marble, followed by limestone, sandstone and granite. Obviously, these are the most frequent rocks employed in monumental architecture but there are also considerable studies on obsidian as a substantial raw material in prehistoric societies (see ASMOSIA 1988, 1992, 1995, Ericson 1984, Torrence 1984).

In order to reconstruct the social value of raw materials or objects, we have to closely observe the patterns of their use, the context in which they are found, their provenance and movement, the variations in distribution and demand, which will ultimately determine whether there is unequal access to these goods, linked with some kind of social strategies which rule their exploitation and consumption (Ericson 1984, Torrence 1984, Voutsaki 1994).

In the Late Bronze Age Crete, when monumental architecture was flourishing, gypsum seems to have acquired some kind of social value. This value appears to have been created less by demand, as it usually happened in prehistoric societies, and more by its exclusive use in elite Minoan architecture. The abundance of gypsum outcrops on Crete, in contrast to its limited systematic quarrying and exclusive use in elite buildings, assigns a symbolic significance to the material. Its distribution suggests that there appears to be some kind of control over the outcrops, which restricts its use to specific people or groups that use it selectively in elite structures. This implies some political-social dimensions, with regard to the production and the patterns of consumption that merit a closer examination.

A detailed study of Minoan gypsum can provide evidence concerning its history: provenance, production, distribution, utilisation and finally its decline. As Rockwell notes in his stone working reference guide, "a piece of worked stone has a language inscribed on its surface that can be read from those who have learned the signs. .... The problem is not whether the information exists but rather the identification and interpretation of that evidence" (Rockwell 1993:5). In the case of gypsum not many surface signs have survived weathering, but still every piece of it carries substantial information, which needs to be first identified and then interpreted. The analysis of this information can be applied to the study of quarrying, raw material selection processes, craft specialisation, exchange and modes of transport, and finally social organisation. Furthermore, the conclusions of such a study will contribute to the history of Minoan quarrying.

Besides, before any conservation or restoration interventions can be conducted in a monument, its archaeological significance must be identified and understood, so that the conservation policy can be directed towards the preservation of the surviving evidence and authenticity of the archaeological context. The study of the technology, and use of gypsum in antiquity, will therefore help us to understand its archaeological significance as well as the history of its exposure, which is directly connected with the weathering processes. On the other hand, understanding the causes and effects of weathering will contribute in understanding the use and the exposure of the stone.

The diagnosis of the causes and mechanisms of deterioration is a primary task, which has to be undertaken before any methodology for the conservation and preservation of the stone and consequently of the entire architectural context in which it is found can be considered. In the massive stone conservation bibliography, the studies which refer to gypsum as a building material are as scarce as the archaeological ones (Zezza 1994). Unpublished studies have also been carried out in the framework of the restoration and conservation project of the archaeological site of Knossos (Mourtzas 1992, Kouzeli, 2003). However, it should be noted that considerable experimental studies on gypsum solubility and gypsum - anhydrite transitions are reported in the chemistry literature, as well as extensive studies on the deposition and diagenesis of gypsum in the geology literature (see, Macdonald 1953, Madgin 1956, Kirkland 1973, Harvie 1980, 1984, McConnell 1987, Schreiber 1988 etc.).

It is apparent that the present status of knowledge concerning deterioration factors and mechanisms is not yet sufficient and a systematic approach to the study of gypsum is needed in order to be able to understand the evolution of its decay, and develop the appropriate conservation policy, aimed at the effective and long-term preservation of the material. The objective of the present research is not to suggest a specific conservation methodology but to highlight the causes and the deterioration mechanisms of the material. In conclusion, the tasks of the present research are the following:

A: Evaluation of the archaeological significance of gypsum. This implies a series of questions about the production, distribution and consumption of the material. The following questions arise: In which sites and in what context is gypsum found on Crete, Cyclades and Mainland? What is the value of gypsum and how is this value acquired? Can we identify an organised quarry industry of gypsum controlled by the palaces? Which members or groups of the prehistoric society had access to the material? Which outcrops have been exploited? What methods and tools were used for quarrying and shaping? What kind of skills and labour investment has been required for the execution of the works? Can we identify a specialised class of craftsmen working on gypsum?

B: Diagnosis and evaluation of the major weathering factors and their effects on gypsum decay. Classification of the major weathering forms with an attempt to correlate them with the physical and chemical characteristics of the stone such as composition, structure, crystal size, the architectural function and the environmental and microclimatic conditions to which it is exposed.

1.1 Methodology

For the purposes of this study, detailed quarry surveying and sampling, combined with the analysis of data presented from the sites, are used as the main tools of archaeological research. Macroscopic and microscopic observation, analytical methods such as Scanning Electron Microscope (SEM), X-Ray Diffraction (XRD), and Polarised Light Microscopy (PLM) were employed in the study of the weathering processes. In order to understand the interaction of the environment in gypsum weathering, a full year relative humidity (RH) and temperature (T) monitoring was undertaken at Knossos in three different locations which represent the different conditions of exposure (unsheltered, sheltered, and reconstructed areas).

The data was collected from the sites by means of detailed recording of each individual gypsum architectural member in a spreadsheet prepared for the needs of this study. The spreadsheet consisted of 16 columns representing an equal number of variables which cover all the information required for both major aspects of this study: the archaeology and the deterioration of the material. Apart from the entry number and the name of the site the following information is included in the recording of every piece of gypsum:

Location: number or name of the room as given by the excavators.

Orientation: the orientation of the exposed surface of block or slab when found *in situ*.

Function: the apparent function of each architectural member.

Date: the date as suggested in the existing publications.

Reuse: a note is made to indicate possible reuse in a later period.

Dimensions: height, width, length or diameter when required, accompanied by a separate note or drawing when the shape is other than rectangular (e.g. triangular). The dimensions recorded reflect the original shape, including the restored parts of the blocks and dadoes and not the preserved dimensions.

Volume: as derived from the calculation of the measured dimensions. In areas where we cannot be sure about the original dimension e.g., height of dadoes, the maximum preserved has been used for the estimation of the total volume of gypsum that has been used.

Percentage of remaining material: this percentage represents the amount of the remaining volume in proportion to the estimated original volume.

Variety: the variety is indicated according to a classification which has been established for the purposes of this study, but was subject to modifications as the research developed and new criteria for the grouping of the varieties arose. The main characteristics which determined the variety were the crystal size and morphology and the rock texture (e.g. coarse crystalline, massive nodular, laminated etc.).

Colour: an indication of the colour including the different tones of veining is given, according to a classification established for this purpose e.g. grey-white veined if the predominant colour is grey or white-grey veined if the predominant colour is white.

Weathering forms: the weathering forms, which can be macroscopically observed on the stone surface, were recorded according to the classification system of Fitzner (Fitzner *et al.* 1995), with the addition of weathering forms which are unique to gypsum such as the 'weathering crust' and the 'polygonal fissures' (Macaluso and Sauro 1996,1998,2003).

State of preservation: an assessment of the preservation state of the stone is made by means of damage categories. Following the model of Fitzner again, five categories have been established: i) very slight, ii) slight, iii) moderate, iv) severe, and v) very severe damages (Fitzner *et al.* 1995:72).

Previous conservation interventions: the apparent consolidation or reconstruction interventions were recorded.

Exposure: the environmental conditions to which the monument is exposed were abbreviated as outdoors, sheltered or unsheltered and marked in the record sheets.

Photograph reference number: right angle photographs were taken from representative cases which show distinctive weathering forms were considered as good examples for weathering mapping.

Drawing reference number: drawings of walls, floors, benches and individual blocks or slabs that show some particularity.

In the first period of fieldwork, the study of two buildings, the Megaron Nirou and the 'Pyrgos Country House' was completed. These sites were selected as the most suitable ones, in order to serve as a pilot study for testing the efficiency of the methodology. The criteria for choosing these sites were firstly that they represent examples of the same period from two different areas, central and eastern Crete, and secondly because their size allowed the completion of the study in the given time.

The methodology established for this purpose was proved to be quite sufficient and only a few minor modifications were needed, in order to improve the method of recording and sorting of the data.

The analysis of the data which was gathered provided substantial information concerning the function of gypsum architectural members, the total volume, preferences in varieties, provenance, technology, and stylistic variations. The estimation of the total volume of gypsum used in each site gives an indication of the scale of the building project and the consequent organisation system required for the execution of the work. Stylistic differences in building decoration were also made evident by the different functions of gypsum and the varieties which had been preferred, as well as the different cutting and finishing techniques.

Further, dimension standardisation was examined in an attempt to gather information about the production system i.e. procurement of the material at the quarry site and the Minoan metrical units. Similarities in the dimensions of blocks, doorjambs or dado slabs within a single building may suggest a specialised group of workmen and a standardised production system and have supplied finished architectural elements to the building site. On the other hand differences in the sizes of blocks of the same function could suggest that they were roughened on the quarry and then were further worked *in situ*. Chips of stone attesting to *in situ* cutting and shaping process are sometimes recorded in detailed excavation reports but in this case I was not able to retrieve such information.

Similarities in the dimensions of gypsum architectural elements between sites, could further suggest an organised production system which could produce blocks or doorjambs of standard size and shape which were then sent to the sites where the building project was taking place probably along with a group of specialist that executed the project. An alternative option is that standardised items could have been extracted from different locations by the same group of quarrymen (Rockwell

1993:143).

The hypothesis of an organised production system seems very possible if one considers the sophisticated production system and level of craft specialisation, which emerges from the study of other Minoan production systems such as that of the pottery workshops or stone vases.

1.2 Background history and definitions of Minoan architecture

The first major change in the ancient building technology on Crete was the use of cut stone blocks by the end of the Early Minoan period, a consequence of the introduction of bronze as a raw material for cutting tools. Ashlar masonry appears gradually in the MMI period, as more attention is driven to the outward appearance of buildings. Good examples of ashlar masonry however, are not common in the MM I period, since they are not only rare but also hidden by later constructions (Graham 1962, Shaw 1973:11, Dickinson 1994:154-156).

It should be mentioned here that the boundaries of the archaeological periods of Minoan Bronze Age are not very well defined and have been a subject of controversy over the last decades. Evans established the three main divisions of Early, Middle and Late Minoan periods, each subdivided in three phases I, II, III, based on the pottery shapes and decorations from successive deposits and destruction layers at Knossos. The chronology of these periods derives from their correlation to the very well defined Egyptian periods. However, regionalism presents a problem in chronology as development does not seem to be simultaneous across the island. Moreover, radiocarbon dates of the Thera eruption suggest a shift of more than a hundred years earlier (Hood 1999, Manning 1995:217, Warren 1989:169).

In view of the confusion concerning chronology and due to the nature of my study that refers to a broad period and to time consuming projects, I have been mainly using the 'palatial system' of chronology which was developed by N. Platon and is mainly dependent on the appearance, the destruction and rebuilding phases of the Minoan palaces. According to this system the Minoan era is divided into the Pre-palatial, Proto-palatial, Neo-palatial and Post-palatial periods. In the course of this study I am focusing in the architectural remains of the New Palace period (MMIIIB- LMIA), which constitute the majority of the remains that are visible today.

Cut stone and ashlar masonry become frequent architectural elements in the Old Palace period (MMIB), with the appearance of the first palaces, which open a new chapter in the history of the Island. There is a considerable debate as to how and when the first palaces appear (Warren 1987, Driessen *et al.* 2002). Bronze Age Crete was densely settled and populated and made full use of the fertile Neogene formations for agriculture. The development of the Palaces is related to the consolidation of the power of ruling elites which had emerged slowly from the Early Minoan period. The first palaces however, suffered several destructions and were finally destroyed in the same broad ceramic period, MM IIB, around 1750 BC. Traces of fierce fire are apparent in all buildings and may have been associated with earthquakes. The period of the new palaces is characterised by intensive building activities, greatly increased population, remarkable artistic achievements, trade with Egypt and Syria, and the extension of the Minoan influence through out the Southern Aegean (Driessen 1990).

Major changes are observed in the socio–political organisation, the arts and crafts, script and religion. The old palaces were replaced by more highly organised complexes, which have almost entirely covered earlier remains. Besides, large independent buildings are constructed around Knossos, as well as new palatial centres were established (Driessen 1990, Niemeier 1994, Driessen *et al.* 2002). The appearance of several country houses with palatial characteristics is one of the most interesting developments of this period (Hägg 1997).

According to Warren (1987) the term 'palace' is attributed to the principal building complex at a site, with a central court and perhaps other courts, significant storage facilities, production areas, rooms for administrative records, rooms for ritual activities, and rooms for public activities or reception rooms. In most cases the west wing seems to be the most important sector of the building. With the restriction of the above definition we can recognise palaces at Knossos, Mallia, Phaistos, Galatas, Zakros, Gournia and Petras.

Other sites, such as Mochlos, Pyrgos, Megaron Nirou, Agia Triada, Archanes, Kommos, have central buildings which do not show all the 'palatial features', but are built in the 'palatial architectural style' and must have functioned to a certain extent, as the complexes identified as Palaces in other sites (Hägg 1997, Shaw 2002, Soles 2002). Betancourt (1997) classified these building into three categories based on their location: a) the country villas, standing alone in the countryside, b) the manorial villas, which dominate a small village or town and c) the urban villas, set in a great city or its suburbs.

Palatial architectural style refers to both palaces and smaller outstanding or 'elite' buildings within a large or smaller settlement. Driessen (1990) has divided the architectural features that characterise palatial architecture, into four categories according to the structural characteristics, layout and design, area typology, and the architectural decoration.

The most important structural characteristics are: ashlar masonry with mortises, orthostates, mason's marks, T- and L-shaped doorjamb bases, columns, pillars, pier and door partitions, columns on balustrades along staircases, drainage system, raised walks and paved roads.

As regards the layout and the design, palatial architecture is characterised by the organisation of the buildings in functional units, as well as the organised circulation through corridors, and the installation of central and west court provided with porticoes. Special attention seems to be paid to the west wing.

The area typology refers to the functional character of certain rooms or units, which is actually what mostly demonstrates palatial elements. New types of rooms in the New Palace period include: the Minoan hall, lustral basin, light well, stoa, veranda, portico, stone staircase with multiple flights, and tripartite shrine.

The fourth category of palatial features is the architectural decoration and it is within this context that gypsum is examined. The use of ashlar itself has some decorative aspect, as well as the use of stones with decorative qualities. The extensive use of gypsum as a facing to walls and floor pavements is traditionally thought to be one of the most distinctive features of Minoan architecture. The gypsum *triglyph* benches, the fresco decorations, the polychrome wall relief panels and the "mosaico" floors, consisting of a central panel contrasting to the surrounding paving, are some of the finest and most characteristic elements of Minoan architectural decoration. The horns of consecration although of primary ritual character, can also be considered as decorative elements as well as some structural elements such as the orthostates set on a projecting *krepidoma*.

According to the above definitions gypsum is used systematically only in buildings that are built in the palatial architectural style. Amongst them we can identify two palaces (Knossos and Phaistos), three 'manorial villas' (Agia Triada, Megaron Nirou, Pyrgos) and various 'urban villas' around the Palace of Knossos (Royal Villa, South East House, South House, House of the Chancel Screen, House of the Frescos etc.). The central building of Pyrgos however, is usually referred to as a 'country house' which is the term that the excavator preferred as more accurate and representative for a house far from urban centres (Cadogan 1997).

The Little Palace and the Temple Tomb are not classified in any of the above categories due to their special and unique character. As Hood (1997) notes "the size and the splendour of the Little Palace place it in a class on its own". The same is true for the Temple or Royal Tomb a clearly non residential building of strongly religious character.

The five buildings that were used as study cases for the use of gypsum in Minoan palatial architecture represent two categories: the palace and the 'manorial villa' considering that the Pyrgos country house falls into the latter.

1.3 Cut stone in Minoan architecture

Ashlar masonry consists of cut stone well shaped and placed carefully in successive horizontal courses of equal height. The types of stone preferred for ashlar masonry in Minoan architecture were porous limestone locally known as 'poros', sandstone, and gypsum, chosen on the basis of their working properties and the local availability.

Limestone or poros is the most frequent type of stone used for ashlar masonry, and occurs in various sites, such as Knossos, Agia Triada, Phaistos, Petras, Archanes, Tylissos, Vathypetro, Megaron Nirou and Pyrgos. Finer and more compact grades of whitish - creamy, and grey - bluish limestone, were often preferred for paving slabs, bases, stylobate slabs, which were generally subjected to greater stresses than wall blocks. There is also a unique example of compact whitish limestone wall dadoes at the 'palace' of Petras.

At Mallia, Zakros, Palaikastro, Gournia and Mochlos the most frequent stone was sandstone extracted from the local quarries. The building materials of Galatas, the most recently excavated Minoan palace, have not been examined yet but macroscopic observation suggests that the building material is mainly local limestone. Other types of stone, used on a small scale, have also been identified such as varieties of harder limestone for pavements, thresholds, bases, schist in the form of flat slabs, conglomerate, crystalline limestone, ophiolite, and marble (Shaw 1973:11-43, Soles 1983, Driessen 1984, Evely 1993: 207-217, Pike 1998:377, Papageorgakis 1992, 1993, Pike 1998).

Gypsum is the third most frequent type of stone utilised for cut blocks and slabs, in palatial architecture after sandstone and limestone. It is the principal stone used in the

Knossos area for both structural and ornamental purposes, while at Phaistos and Agia Triada, it has more of an ornamental character. It is clearly treated in a different manner from limestone and sandstone, with a number of decorative and structural applications. Quarried and shaped gypsum was used since the MM period at Knossos and Phaistos. Earlier examples of gypsum used in building construction can be seen at Knossos and Myrtos-Phournou Koryphi, but the stone was probably gathered from the hillsides rather than quarried.

A classification of the main gypsum varieties used in Minoan architecture is given in Chapter 3 while the different functions that gypsum has performed and the corresponding varieties are discussed in detail in Chapters 4 and 5.

1.3.1. Clarifications on the terminology used in stone studies

A common problem in the archaeological literature, as far as the stone studies are concerned, is the lack of a common terminology. General colloquial terms are often adopted by archaeologists, architects and builders and are used with no reference to the geological terms that describe accurately the nature of the rocks. The same general term is often used to describe different rocks with similar characteristics while on the other had different terms are also frequently used for the same type of rock. For example the terms '*poros*' and '*porolithos*' are used to describe fossiliferous limestone, travertine and sometimes calcareous sandstone. The latter is also called 'ammoudopetra' when soft and coarse grained. It is therefore necessary to clarify the terminology that refers to the types of rocks that are mentioned in this volume with reference to the geological and the local colloquial terminology that is used on Crete. Wednesday

Papageorgakis (1988 and 1993) classifies the main types of rocks that are used in the construction of the Palace of Knossos and gives a good account of the local terms and while Dermitzakis (1990) and Moraiti (1991) describe the rocks types of the Phaistos area. According to the aforementioned studies and to my field research the most common types of rocks that can be identified in the examined buildings and are mentioned in the text, are the following:

Pure limestone: white-creamy compact limestone (calcite-$CaCO_3$- calcium carbonate), locally known as '*asbestolithos*' or '*peleki*' (east Crete).

Marly limestone: yellowish, less compact and soft limestone (calcite-$CaCO_3$- calcium carbonate),, locally known as '*kouskouras*'

Fossiliferous or Biogenic limestone: yellowish, brownish to light grey limestone (Calcite-$CaCO_3$- calcium carbonate), rich in micro- and macro-fossils, with high porosity, locally known as '*poros*' or '*porolithos*'.

Travertine: yellowish to brownish usually hard form of calcium carbonate (calcite-$CaCO_3$) that is deposited from the water of mineral springs (especially hot springs) or streams holding lime in solution. Porous travertine is also locally known as '*poros*' or '*porolithos*', while more compact veined travertine is known as '*alavastro*'.

Platy crystalline limestone: bluish grey, compact, hard limestone of the Plattenkalk series of Crete (calcite-$CaCO_3$- calcium carbonate), locally known as '*sideropetra*' of '*titanolithos*'

Tripolis limestone: grey to bluish, dark grey or even black limestone of the Tripolis series of Crete (calcite-$CaCO_3$- calcium carbonate), locally known as '*sideropetra*' as well.

Sandstone: yellowish, brownish to light grey, fine- to coarse-grained sandstones, largely composed of quartz and usually cemented in a calsium carbonate matrix, (occasionally in siliceus matrix as well), localy known as '*poros*' or '*porolithos*' when they show high porosity.

Gypsum: A) **Alabaster**: white and often veined, compact, microcrystalline diagenetic or secondary gypsum (calcium sulphate dehydrate $CaSO_4$), localy known as 'alavastro'. In Egypt however, the term alabaster is used for travertine, the rock of which the Egyptian vases known as 'alabastra' are made of. B) **Selenite**: translucent, coarse crystalline primary gypsum (calcium sulphate dehydrate $CaSO_4$), locally known as 'gypsopetra' or 'selinitis'. C) **Laminated gypsum**: cream-yellowish, often veined, laminated fine grained primary gypsum (calcium sulphate dehydrate $CaSO_4$), locally known as 'gypsopetra' in Greece and as 'balatino' in Italy.

It is apparent that the terminology that is used by local workmen and is often adopted by archaeologists can be quite confusing, since general terms are applied to all types of stone that show similar characteristics. It is therefore understood that geological and petrographic studies should be carried out before we are able to identify and describe the building materials of a site and to locate the possible sources of provenance.

1.4 Use of gypsum: a comparative perspective

Most early cultures in the Aegean, and the Near East used gypsum for the production of vases and plaster. In Egypt the fine grained variety of gypsum 'alabaster' was quarried systematically for the production of plaster and for the manufacture of vases from the fourth millennium BC (from the Pre-dynastic Period to the end of the Third Dynasty). Gypsum was also the main material used as wall and ceiling plaster, as background for wall paintings, and backing for inlays. Other applications include jar sealings, the modelling on Old Kingdom mummies, the Amarna Portrait masks and binding for stone masonry (Shaw 1994, Nickolson 2000:21-22).

Gypsum plaster is in fact the most common and one of the oldest building materials in the world. It also known as 'plaster of Paris', or 'calcined gypsum' (USA) or 'Stuckgyps' (Germany) and consists of powdered calcium sulphate hemihydrate, that is the low temperature dehydration product of gypsum. Commercial hemihydrate is produced by heating gypsum at 150° -200°C, over a period of one to three hours. This temperature is very low when compared to that required for lime (900-1000^{0}C), which explains the extensive use of gypsum plaster in Egypt and Mesopotamia where wood resources were limited. It easily reabsorbs moisture and re-crystallises as gypsum ($CaSO_4$•$2H_20$), regaining that way its rock-like characteristics. When mixed with water it forms a paste that soon after (30-60 mins) becomes solid.

The burning of gypsum for the preparation of plaster has been a quite early practice, which dates back to 4000 BC at least. In Mesopotamia gypsum plaster was manufactured from the time of the Early Uruk (4000 BC) with several applications including brick casting, floor and wall plastering, in mortar mixed with mud, as well as in various room fittings such as niches and chimney hoods.

Assyrians employed alabaster, the fine grained variety of gypsum, known in Iraq as 'Mosul Marble', for sculpture as well as for carved reliefs on orthostates, which adorned the walls of royal palaces and temples, but not substantially until the Neo-Assyrian period (1000-612 BC) from the reign of Assurnasirpal II, 883-859 BC (Middlemiss 1953, Moorey 1994:328-332, 336-337, 343, 347).

Alabaster has also been used extensively in Italy and Sicily mainly as an ornamental stone for sculpture and the decoration of interiors. Some of the most outstanding examples of gypsum sculpture are the Etruscan alabaster cinerary urns from Volterra which date back to at least the 6^{th} century BC. Alabaster was also used by several sculptors in the Renaissance including Michelangelo. The windows of the Galla Placidia Mausoleum in Ravenna, the main source of indoor light are made of yellow-orange alabaster (Bromehead 1943, Dimes 1990:125).

Gypsum is still used today for the production of sculptures, lights, and other small ornaments in Volterra and Florence. Italian craftsmen often treat the fine-grained translucent alabaster in hot water in order to create an opaque white surface which closely resembles fine Carrara marble. The whitening of the surface is the result of partial dehydration and rearrangement of the crystal structure. It is noted, however (Taylor 1933), that if the temperature is not carefully regulated "the stone becomes dead, chalk white and its appearance being irreparably ruined". The material obtained with this technique is known as 'Marno di Castellina' owing its name to the area of Castellina which is the source of the finest quality of alabaster in Italy (Bromehead 1943, Detwhiler 1955, Dimes 1990:125-127, Taylor 1933, Winkler 1973:20, Yeager 1971).

That the Romans recognised the fire protective ability of gypsum is suggested by transcripts of Roman laws, which refer to dire penalties that were given to the builders of an un-plastered house which had been destroyed by fire and whose occupants had failed to escape (Yeager 1971). Pink alabaster is also found in Cyprus in the area of Kourion where is has been used for paving slabs at the Nymphaion, 1^{st} –7^{th} AD, and other buildings of the same period.

Despite the decorative character of gypsum its main application from the past up to now is the production of plaster. Industrial production of gypsum began in the early 20th century and soon became one of the major factors in the building industry. Since 1950's gypsum plaster was used extensively in the USA in fire resistive high rise structures. Gypsum uses expanded so rapidly that in 1970's the world's production was over 60 million tonnes per year, of which the 25% was consumed by the building industry of the States (Yeager 1971, Drougas 1980).

Today it is largely quarried in North and South America and in Europe, for the production of plaster of Paris, with major producers the USA, Canada, and France. Gypsum plaster finds numerous applications in the building industry mainly as wallboard and binding material, in decorative arts, paper manufacture and ceramic industry. Raw gypsum also finds applications in agriculture and even in brewing (hard or selenitic water is the best for brewing ale) (Dimes 1990:127). In agriculture gypsum is commonly applied as a soil amendment to reclaim sodium affected soils and as a water amendment, to reduce the sodium hazard in irrigation waters (Tanji 1969).

CHAPTER 2

2.1 Physical and Chemical Properties of Gypsum

The physical and chemical properties of gypsum are examined in this chapter in order to give the reader a background on the nature of the stone, which will ultimately help in understanding the issues that relate to its exploitation and utilisation as well as its behaviour as a building material and the weathering processes to which it has been subjected.

2.1.1 Crystal Structure

Gypsum rock consists predominantly of mineral calcium sulphate with two molecules of crystalline water. The water molecules in gypsum are kept together by relatively weak hydrogen bonds. Elimination of any amount of water from gypsum is accompanied by alteration of the initial crystal structure and the formation of lower hydrates characterised by a different crystalline lattice. Four principal phases have been distinguished in the system calcium sulphate - water: $CaSO_4 \cdot 2H_2O$ (in mineral form, gypsum), $CaSO_4 \cdot 1/2H_2O$ (mineral bassanite), γ-$CaSO_4$ (soluble anhydrite), and β-$CaSO_4$ (mineral anhydrite). A fifth phase is the high temperature dehydration product α-$CaSO_4$ (Weiser *et al.* 1936, Posnjac 1938, Florke 1952).

The various names commonly used to describe components and phases of the system $CaSO_4 \cdot 2H_2O$ are listed in Table 2.1.

However, the number and the nature of the solid phases of the system calcium sulphate – water has been a quite controversial subject. Most studies conclude that hemihydrate is a definite compound with a characteristic crystal structure distinct from that of 'soluble anhydrite' (Weiser *et al.* 1936, Posnjac 1938).

The structure of the hemi-hydrate as suggested by Florke (1952) is a rombohendral one and is distinct from that of γ-calcium sulphate (Florke 1952:173, Hammad 1981, Lager 1984, Deer *et al.* 1996).

Some scholars suggested six solid phases in the $CaS0_4$-H_2O system with distinct thermodynamic properties: gypsum, two polymorphs of the hemihydrate (α and β), two polymorphs of soluble anhydrite (α and β), and anhydrite (Hamad 1981, Kelly *et al.* 1941, Mc Ardie 1963).

The crystal structure of calcium sulphate phases is presented in the following paragraphs, in order to provide information that will help in understanding the physical properties of the stone which relate to its suitability for decorative and building purposes and its behaviour to weathering.

2.1.1.1 Gypsum ($CaSO_4 \cdot 2H_2O$)

The crystal structure of gypsum was determined by Wooster in 1936 (X-Ray Diffraction data), further defined by Atoji and Rundle in 1958 (Neutron Diffraction data) and revised by Cole and Lancucki 1972 (Three-Dimensional X-Ray Diffraction data). The crystal structure has space–group symmetry with four $CaSO_4 \cdot 2H_20$ per unit. It is generally described as a layer lattice structure, where the binding between the atoms within the layers is stronger than that between the layers (Wooster 1936, 1938:35). Calcium sulphate and water molecules are arranged in alternating layers parallel to the (010) plane, which is related to the perfect cleavage of the stone at that plane (Fig.2.1).

Calcium sulphate layers are built up from chains of calcium atoms and sulphate groups. Sheets of SO_4 ions, bound together by Ca ions, alternate with two parallel layers of water molecules, parallel to the (010) plane (Fig.2. 2). In gypsum crystal structure, there are two crystallographically distinct sulphate oxygen atoms, O1, and O11 and a third is the Ow atom of the water molecules. Each Ca ion is surrounded by one pair of O1,O1′ and two pairs of O11,O11′ which belong to the sulphate groups and by two Ow from two water molecules. Each atom of the O1,O1′ pairs is hydrogen bonded to two molecules of water, whilst the O11,O11′ have no hydrogen bonds but are close to Ca^{2+} ions. As a result of the different environment surrounding the symmetry related pairs O1,O1′ and O11,O11′, the distances in between the oxygen atoms of the sulphate ion are not all the same and therefore its symmetry is reduced (lower than tetrahedral) (Cole & Lancucki 1972, 1974).

The water molecules lie near a calcium ion and two oxygen atoms (of sulphate groups) to which, are hydrogen bonded. The Ow—H1 and Ow—H2 distances in each water molecule are non-equivalent and have different length (Fig.2.2-2.3). This indicates an asymmetry of the H_20 molecule, which is connected with the hydrogen bonding to the O1 atoms of the SO_4 groups (Seidl *et al.* 1969). Cole and Lancucki (1972) have reported a considerable difference (0,008 Å) in the length and strength of the hydrogen bonds of the OH1 and OH2 groups in gypsum. The shorter bond is always associated with the atom H1 and the longer one with H2.

The H2 atoms are located within the double layer of water, forming bonds almost normal to it, while the H1 atoms are always outside it and form shorter and stronger bonds which are parallel to the water layer (Fig.2.2-2.3) (Cole & Luncucki 1974:928, 1973:105, Florke 1952:172, Deer *et al.* 1996).

The positions of hydrogen atoms have been determined by the method of proton magnetic resonance (Pake 1948). Details of the structure and bonding of the $(S04)^{-2}$ ions and the water molecules have been determined by Raman spectrum (Rousset & Lochet 1945), infrared spectrum studies (Hass & Sutherland 1956) and by neutron diffraction (Atoji & Rundle 1958).

The direction (001) is that in which Ca and O ions are closest together and this corresponds approximately with the direction of fibrous cleavage, small expansion, coefficient ($2x10^6$), and high refractive index. The expansion coefficient is greater ($42x10^6$) for the direction perpendicular to the perfect cleavage, and on heating it results in a rapid decrease in the refractive index for this vibration direction and the consequent change in optic axial plane. Thermal conductivity is also anisotropic, being greater in the direction parallel to the layers and less in the direction perpendicular to them (Deer *et al.* 1996, Wooster, 1936, 1938:35, 85). The anisotropy of gypsum, which is directly related to the structural characteristics that were described above, and especially the distribution of water molecules within the crystal, presents special interest as regards the weathering behaviour and morphology, which will be discussed in Chapter 7.

2.1.1.2 Hemihydrate ($CaSO_4$ ½ H_2O)

The crystal structure of hemihydrate has been the subject of numerous studies because of its importance in the building industry. The relevant literature has been reviewed and discussed by Florke (1952), who has investigated all the phases of the system $CaSO_4$ – H_2O. The hemihydrate lattice comprises by continuous chains of successive calcium and sulphate ions, which are parallel to the c axis. The c axis is parallel to that of the original structure of gypsum, with length twice as large. The sulphate ions form tetrahedra and the Ca atoms are surrounded by eight oxygen atoms, located at almost equal distance, which belong to the sulphate groups (Fig.2.4).

The remaining water molecules are located within the wide channels that occur through the position of the chain axes. Water is probably linked with hydrogen bonds to the oxygen atoms of the sulphate groups (Florke 1952:176, Lager *et al.* 1984).

According to Florke (1952) the hemihydrate exists in two forms the orthorhombic, which occurs in temperatures up to 45°C, and the trigonal in temperatures above 45°C. The same distinction between α and β-hemihydrate is made by McArdie, who suggests that the two forms α and β are the terminals of a series of hemihydrates, which differ in the packing of the Ca-$S0_4$ chains with respect to each other, and the rotational orientation on the SO_4 tetrahedra along the chains (McArdie 1963: 800).

Hemihydrate, or bassanite, is formed as an intermediate phase during the transformation of gypsum to anhydrite at high temperatures (over 88°C) or high brine concentration. The formation of bassanite as an intermediate mineral depends on the relative supersaturation of the brine with respect to this mineral. Due to the structure of hemihydrate the uptake of ions is larger than that of the other calcium sulphate phases. The sulphate oxygens create a negative field in the tunnels, which stabilises any cations that may have penetrated the crystal. Bassanite grown in NaCl solution can contain up to 3% Na. Incorporation of Na in the tunnels results in greater thermal stability of the hemihydrate as the presence of $Na+$ can inhibit the movement of water. The addition of small amounts of NaCl or KCl in gypsum retards dehydration (Budnikoff 1935, Kushnir 1981, Lager et al 1984).

2.1.1.3 Soluble Anhydrite (γ-$CaSO_4$)

Accepting the hemi-hydrate as a specific compound, γ-$CaS0_4$ may be described as a dehydrated hemihydrate (Fig.2.4-2.5). Its crystal structure is basically the same as that of hemihydrate, without the molecules of water in the channels. The dehydration of hemihydrate to γ-$CaSO_4$ requires only a small amount of energy and the atoms retain their position in the lattice. The basic structural unit of γ-$CaSO_4$, common to all phases of the $CaSO_4$ – H_2O, is the chain of edge-sharing SO_4 tetrahedra and CaO_8 polyhedra (Fig.2.5-2.6).

The γ-$CaSO_4$ is very unstable and is immediately converted to either $CaSO_4 \bullet 1/2H_2O$ or β-$CaSO_4$ (Florke 1952:223, Lager *et al.* 1984, Borisenko 1965:5). This can be explained by the nature of the bonds in the dehydrated structures. Both in hemihydrate and γ-calcium sulphate, the SO_4^{-2} ions are distributed in a way that they are facing each other or facing Ca^{+2} ions. Consequently, the bonds between the ions of the same charge are relatively weak, and the water molecules can easily been introduced between the ions during the re-hydration process (Borisenco 1965:5).

2.1.1.4 Anhydrite (β-$CaSO_4$)

The unit cell in anhydrite's crystal structure is orthorhombic. The basic structural unit is the same as the one described in the structures of gypsum, hemi-hydrate, and γ-$CaS0_4$ (Florke 1952, Borisenco 1965 Lager et al 1984, Deer et al 1996). Parallel to z the structure forms chains of Ca atoms alternating with $S0_4$ groups, with wide channels between them. The structure of anhydrite is illustrated in Fig.2.7 (Dickson and Binks 1926).

Planes containing evenly spaced Ca and $S0_4$ ions lie parallel to (100) and (010), whereas layering is not so well defined parallel to (001). This justifies the better cleavage on

(100) and (010) than on (001) (Deer *et al.* 1996).

The process of dehydration is largely anisotropic, but the initial shape of the crystalline lattice of gypsum can be preserved during dehydration, resulting in a pseudostructure. Atoji (1959) showed that heating a large single-crystal of gypsum to about 500°C in air enhanced the (010) cleavage and gave rise to a pseudomorphous polycrystalline block of needle-shaped crystals of anhydrite. Apart from the enhancement of the cleavage parallel to the (010), the shape and the cleavage properties of the polycrystalline anhydrite remained the same as those of the original gypsum block. This alteration macroscopically results in the loss of translucency of the initial crystal (Fig.2.8-2.11). Microscopic examination of the dehydrated block showed that the water molecules have been driven off in the direction parallel to the (010) and that the dehydration process gives the least effect to the (101) plane (Atoji 1959, Borisenco 1965)

In conclusion, all the structures in the system $CaSO_4$-H_20 can be interpreted by a model of different packing of chains containing Ca^{2+} and SO_4^{2-} ions. Gypsum is characterised by a layered structure with water molecules distributed in inter-layers, the hemihydrate and γ-$CaSO_4$ by a tunnel structure (AIII) and the α and β-$CaSO_4$ by a rather closed packed arrangement (AII). The arrangement of the chains is schematically shown in Fig.2.8. It is apparent in the schematic representation that hydration and dehydration of gypsum within the tunnels, is topotactic and that the basic structural elements, the chains of alternating SO_4^{2-} and Ca^{2+} ions, are preserved (Abriel et al 1990).

2.1.2 Phase transitions in the system $CaSO_4 - H_2O$

The hydrated form of calcium sulphate is usually stable when exposed to the air at ordinary pressure because the partial water vapour pressure of the atmosphere is greater than its dissociation pressure. When heated to a temperature at which the dissociation pressure of gypsum becomes greater than the surrounding water vapour pressure, it begins to dehydrate.

Baldin (1991) made an attempt to explain the dehydration of $CaSO_4.2H_20$ based on a quantum mechanical approach. He shows that the dehydration of gypsum at molecular level begins with proton re-arrangement of OH groups, which results in the formation of water molecules in the crystal lattice (at the places of OH groups).

The spectroscopic energy of dissociation of gypsum represents the energy of the elementary event of proton migration and not the energy of rupture of a hydrogen bond. The adsorbed water molecule passes from one electron excited state to another according to the activated diffusion model. When large molecules are formed they begin to collide on the walls of the narrow micro-capillaries and capillary diffusion takes place. The gaseous water molecules move along transport channels, which determine their free diffusion, which is quite complex.

The transition temperature, as well as the products of gypsum dehydration, have been the focus of several studies since early this century, due to the extensive use of gypsum in the building industry (e.g. Parsons 1927, Budnikoff 1936, Florke 1952, West & Sutton 1954, Ljunggren 1960, Hamad 1981, Lager *et al.* 1984, Abriel *et al.* 1990, Baldin 1991).When heated in air, gypsum starts dehydrating slowly at about 70°C and then rapidly at 100°C and above. At this first phase of dehydration, gypsum loses three quarters of its water of crystallisation as it gradually converts to hemihydrate. The final dehydration starts at about 185°C with the formation of γ-anhydrite up to 250°C, which is successively transformed to β-anhydrite. The dissociation pressure of hemihydrate – γ- anhydrite is very low and consequently this conversion is easily reversed (McConnel

1987, Posnjac 1938).

In continuous heating the transformation of γ-anhydrite to β-anhydrite is completed at about 400-410°C. β-Anhydrite is the stable form of anhydrous calcium sulphate up to 1195°C. Above this temperature it converts to α-anhydrite (enantiotropic inversion). With further heating, up to 1385°C, anhydrite dissociates to form CaO and SO_3 (West & Sutton 1954).

Differential Thermal Analysis (DTA) curves of gypsum (Fig.2.9) show a double endothermic peak between 100° and 200 °C, a small exothermic peak at about 400^0C, and another two endothermic peaks near 1200°C and 1400°C. The first endothermic peak at 180^0C represents the loss of 1 ½ molecules of water and the second at 200^0C the loss of the remaining water. The small exothermic peak represents the conversion of γ-$CaSO_4$ into β-$CaSO_4$, the next two endothermic peaks correspond to the conversion into α-anhydrite at about 1225°C and the dissociation of $CaSO_4$ near 1400^0C (Billo 1986, Ljunggren 1960, Popp & Kern 1993, Tanji 1969, West 1954).

In the literature, however, the transition temperatures in between the different phases of calcium sulphate, show considerable differences due to the different conditions under which the dehydration experiments were carried out. The range of temperature values, which are reported in the bibliography for each transition at atmospheric pressure, is shown in Fig.2.10 (West 1954, Florke 1952, McConley 1958, Ljunggren 1960, Borisenko 1965, Deer 1966, Abriel *et al.* 1990, Popp & Kern 1993).

Temperature is in general the major factor in gypsum dehydration. Pressure may accelerate the dehydration process, but at low temperatures pressure alone cannot activate dehydration (McCormac 1926, Borisenko 1965, McConnell *et al.* 1987,).

The conversion of gypsum to hemihydrate under atmospheric pressure and at temperature of 20°C takes long geological period of time (Fig.2.11). The complete dehydration of gypsum under natural conditions is even more difficult.

As regards the hydration of anhydrite, this usually happens through dissolution and precipitation or by diffuse hydration due to the penetration of water into the crystal lattice (Pechorkin 1983). Ljunggren (1960) reported that samples heated up to 580°C, convert to gypsum when mixed with water, those heated in temperatures in between 580° and 650°C change only partly, while the ones heated to temperatures above 650°C do not change at all.

Connley & Bundy (1958) and Leininger (1957), however, have shown that conversion of anhydrite to gypsum can be activated by alkali sulphates through the formation of transient salts. The hydration process depends on the concentration of the activator, the temperature and particle size. The dehydration of hemihydrate is easily reversed under atmospheric pressure and temperature, when exposed to damp air. As explained in the crystal structure of hemihydrate and γ-anhydrite, the SO_4^{-2} ions are distributed so that they are facing each other or are face Ca^{+2} ions. The bonds between the ions of the same charge are relatively weak, and the water molecules can easily be introduced between the ions during the re-hydration process (White 1926:22, Borisenko 1965:5).

The process of dehydration-hydration of gypsum is accompanied by volumetric changes of two kinds: swelling during hydration and shrinkage during drying dehydration. Dehydration of gypsum to hemihydrate is followed by 15.68% reduction of weight and 34.37% reduction of volume. After further dehydration into anhydrite the reduction in weight reaches 20.9% and the reduction in volume reaches 37.59%. Conversion of hemihydrate to gypsum is followed by 18.3% increase in weight and 52.3% increase in volume. Hydration of anhydrite results in a 26.4% increase of its weight and increase of volume to the extent of 60% (Shcreiber 1978, Pechorkin 1983, Karni 1995).

The volumetric change is calculated according to the following reactions:

Dehydration

GYPSUM → HEMIHYDRATE + WATER

$CaSO_4 \cdot 2H_2O$ → $CaSO_4 \cdot 0{,}5H_2O + 1.5H_2O$

Volume= 74.20 cm^3/mole 48.70cm^3/mole

Volume reduction = 34,37%

GYPSUM → ANHYDRITE + WATER

$CaSO_4 \cdot 2H_2O$ → $CaSO_4$ + H_2O

Volume= 74.20 cm^3/mole 46.31cm^3/mole

Volume reduction = 37.59%

Hydration

HEMIHYDRATE + WATER → GYPSUM + WATER

$2CaSO_4 \cdot 0{,}5H_2O + 3H_2O$ → $2CaSO_4 \cdot 2H_2O + 2H_2O$

Volume= 48.70cm^3/mole 74.20 cm^3/mole

Volume increase = 52.3 %

ANHYDRITE + WATER → GYPSUM

$CaSO_4$ + $2H_2O$ → $CaSO_4 \cdot 2H_2O$

Volume= 46.31cm^3/mole 74.20cm^3/mole

Volume increase = 60.22%

It is apparent from the above calculations that the major fluctuation in volume during dehydration-hydration cycles occurs during the first stage of dehydration of gypsum to hemihydrate and vice versa. As will be seen in Chapter 7, this explains the severe cracking of the gypsum ashlar blocks and orthostates at Knossos that have been burnt at low temperatures by fire during the several destruction phases of the building. X-Ray Diffraction (XRD) of burnt samples show no traces of anhydrite or hemihydrate, which suggests that gypsum was not completely dehydrated to anhydrite but converted to hemihydrate which was later on hydrated, thereby returning to gypsum with a different crystalline structure, often pseudomorphosed.

The dehydration reactions also provide an important fluid source, which produces an increase in pore fluid pressure. The presence of fluids in a rock influences all the properties measurable by physical means, such as elasticity, conductivity, thermal and mechanical properties. The physical properties of the rock change due to the internally created pore fluid, porosity change, pore pressure and also because of the reorganisation of the fabric (i.e. development of fine granular aggregates of dehydrated material in the crystal boundaries). Pore pressure excess is initially generated due to the release of fluid but the consequent decrease in the solid volume results in enhanced porosity and permeability, which improve the system's efficiency to drain the excess pore pressure (Wong *et al.* 1991, Popp & Kern 1993,).

The evolution of porosity and permeability during dehydration is controlled by the rate of increase in pore volume and the rate of pressure induced compaction, which are two competitive mechanisms. Measurements of the changes in pore fluid volume of gypsum rock during dehydration, as a function of temperature, confining pressure, pore pressure and time (Ko *et al.* 1991), have shown that the first mechanism dominates, resulting in an increase of porosity and permeability and enhancement of fluid flow. The rate of fluid release during dehydration depends on the temperature as well as the storage capacity of the pore space (Ko *et al.* 1991, Popp & Kern 1993).

It is therefore clearly understood that the physical properties of dehydrated rock differ substantially from those of the unaffected rock and that the dehydration process is closely related to the weakening of the fabric and the development of certain weathering features which will be discussed in Chapter 7. It should also be noted here that both the aesthetic and physical properties of the dehydrated rock no longer correspond to those of the initial rock, which the Minoan builders required (as revealed by the varieties of the stone that they used), and that before judging their choices we should first understand the characteristics of the original stone before dehydration.

Finally, one of the most important properties of gypsum as a building material, directly related to its thermal behaviour, is fire resistance. In the case of fire near gypsum, dehydration starts on the exposed surface and slowly penetrates into the bulk of the material. The dehydrated layer, which is formed on the surface, retards the dehydration process. The materials behind a gypsum structure will not reach temperatures more than 150°C until dehydration is completed. Since this is much lower than the ignition temperatures of most building materials gypsum can serve as a fire retardant (Drougas 1980, Karni 1995).

Experimental work by Drougas and Kostandinidou (1980) (Fig. 2.12), has shown that after 15 minutes of exposure to fire, dehydration will have penetrated to a depth 0.63 cm. At that depth the temperature does not exceed 100°C. After two hours of heating dehydration has reached a depth of 5cm, surface temperature is 1000°C, at a depth of

2.5 cm temperature is 510°C, at a depth of 5cm is 105°C, at a depth of 10cm is 85°C and at the back side of the slab with 12 cm thickness the temperature reaches just 55°C. Therefore, a 5cm thick slab can protect a wooden structure behind it for at least two to three hours as the ignition temperature for wood varies from 175° C to 235° C (Drougas 1980:5).

2.1.3 Solubility

Solubility of gypsum in pure water and in various salt solutions with regard to gypsum – anhydrite transition, has been extensively discussed in the bibliography due to its geophysical geo-technical and industrial significance. The most representative publications on this aspect are: Cameron 1901, Hullet 1902, 1905, Posnjak 1938, 1940, Scholander 1952, Madgin 1956, Bock 1961, Zen 1965, Hardie 1967, Bock 1968, Christoffersen & Christoffersen 1976, Ponizovskii 1979, Harvie & Weare 1980, Harvie *et al.* 1984, Klimchouk 1996.

Posnjak (1938, 1940) determined the solubility of gypsum, hemihydrate and anhydrite in water and in sea salt solutions. The dependence of solubility on temperature is shown in the graph of Fig.2. 13 and the dependence on the concentration of sea salt solution at atmospheric temperature in Fig.2. 14.

The solubility of gypsum in distilled water is 2.08 gr/cm^3, at 25° C (Christoffersen 1976, Scholander 1952:134). It increases with temperature up to 50° C and then drops due to conversion of gypsum to anhydrite and to hemihydrate (Fig.2.13). In increasing concentration of sea salts, solubility increases rapidly up to about the normal salinity of seawater and then only slightly until it reaches a maximum at about twice the normal salinity. It then gradually decreases until the solution reaches 3.5 the times the normal salinity, that is the point at which deposition of gypsum starts (Fig.2.14) (Posnjak 1938, 1940).

Solubility of gypsum as affected by ion association and ionic strength, in low temperature and low electrolyte concentration systems, was studied by Tanji (1966, 1969), who developed a computer programme for the prediction of ion association and solubility of gypsum in simple and mixed aqueous electrolytes. His calculations for gypsum solubility in solutions on NaCl and $MgCl_2$ are shown in Fig.2.15 along with the measurements of earlier workers (Seidell & Linke 1958, Longenecker 1959, Denman 1961, Nakayama & Rasnick 1967, Marshall & Slusher 1968).

In the presence of increasing concentrations of NaCl, the solubility of gypsum is increasingly enhanced because of a decrease in the activity coefficient and increase of $Na_2SO_4^-$ complexation. Solutions of NaCl and Na_2SO_4 also enhance solubility but to a smaller extent. Solubility is also enhanced in $MgCl_2$ and in mixed solutions of NaCl, Na_2SO_4 and $MgCl_2$ (Fig.2.16) (Klimchouk 1996).

In the presence of one common ion (Ca^{++} or SO_4^{--}), the solubility of gypsum is repressed as a result of an increase in activity of the other ion. With increasing electrolyte concentration the solubility is further reduced. As shown in Fig.2.14, the solubility of gypsum decreases in solutions of $MgSO_4$, $CaCl_2$, and Na_2SO_4. However when the ionic strength of the solution is increased by electrolytes without a common ion, then solubility increases accordingly (Scholander 1952, Madgin 1956, Posnjac 1958, Tanji & Doneen 1966, Tanji 1969).

Dissolution velocity is influenced by the temperature and the viscosity of the solution. It is a linear function of temperature, and has a linear dependence on the inverse value of viscosity (Scholander 1952). Dissolution is also directly proportional to the flow velocities of the solvent, which means that it is enhanced an increase of movement on a gypsum surface enhances dissolution. Dissolution measurements on crushed rock as well as large fragments, under different flow velocity of solvent, showed remarkable variations (Fig.2.17) (Peckorkin 1982).

The solvent flow velocity is therefore a major factor in dissolution of gypsum exposed to outdoor environments, which will be further discussed in Chapter 7. Experimental studies have shown that crystal size and type have also some effect on dissolution velocity. Apart from the well known effect of grain size related to surface energy, measurements on three different faces (planes) of the crystal (010, 110, 111) show that dissolution velocities differ in the ratio of 1:1,76:1,88 (Scholander 1952). Finally, gypsum is soluble in weak solutions of HCl and HNO_3 and H_2SO_4 (Scholander 1952).

2.1.4 Mechanical properties

The hardness of gypsum is 2 on the Mohs scale, which means that it can be scratched with the fingernail, and that it has a slightly soapy feel to the touch. It further implies that fine grain varieties can be easily carved in great detail while the coarse crystalline ones would provide mainly flat surfaces. The cleavage properties along with the softness of the stone must have made the extraction of the stone, as well as the cutting and shaping, fairly easy operations with the tools available to Minoan masons.

The specific gravity of gypsum is 2.32g/m^3, and the molecular weight 172,4g/mole. The bulk weight of gypsum (2.32g/m^3) is lower than that of limestone (2.8g/m^3) and therefore the blocks of gypsum would have been easier to handle when compared with limestone, which in Minoan Crete was the most common alternative to gypsum. The low bulk weight also results in low thermal conductivity of 0.2 W/m K, and thermal insulation capability that were the main properties that projected gypsum to the top of world's building industry in the 1950's (Karni 1995).

As already mentioned, the dehydration process affects all the physical and mechanical properties of gypsum. Dehydration is accompanied by an increase in the crack density and progressive opening of the pore space, due to the increased pore fluid pressure. The examination of stress-strain behaviour of massive (granular) gypsum as a function of temperature shows large reductions in strength over a relatively narrow temperature range from 100 to 150°C, which is attributed to the conversion of gypsum into hemihydrate. Similar reductions are observed in the compressional and shear wave velocities as well as the elasticity of the rock (Popp & Kern 1993).

The increase in pore fluid pressure during dehydration also results in the lowering of the effective confining pressure and reduction of the cohesive strength of the material, which is related to the increase in porosity. The reduction in the elasticity and mechanical strength of gypsum during dehydration can explain the development of some of the most prominent weathering features of Minoan architectural gypsum, such as the severe cracking of fired blocks, which will be discussed in Chapter 7 (Kern 1985, Popp & Kern 1993).

2.1.5 Chemical Composition

Gypsum shows very little variation in its chemical composition, the most common impurities being SiO_2, Al_2O_3, Fe_2O_3, MgO, and NaCl. Other minerals often associated with gypsum are celestine, calcite, aragonite, dolomite and pyrite. Amongst the elements found in its chemical composition are: Mg, Si, Ca, Ti, Fe, B, Al, Mn, Cu and occasionally traces of Li, Be, Y, Zr Bi and Ba. In reddish-brown crystals of gypsum the iron content varies between 5 and 230 p.p.m., and the colour appears to be governed by the state of oxidation of the iron (Deer *et al.* 1966: 202-218, Kanaris 1980).

2.1.6 Colour

Gypsum, like most sedimentary rocks, owes its colour mainly to iron oxides such as the red hematite (Fe_2O_3) or ochre brown goethite (FeOOH) and the amorphous $Fe_2O_3 \cdot n H_2O$. Large crystals of pyrite (FeS_2) are usually responsible for the yellow-brass colours while fine grained or amorphous crystals of ferrous sulphide give dark colours to deep black. Dark colours are generally produced by ferrous iron (FeO) and red-orange and yellow colours by ferric iron (Fe_2O_3). The colour of the sedimentary rocks is largely dependent on the FeO/Fe_2O_3 ratio. Iron oxides are generally unstable when exposed to light and weathering and often undergo changes that affect their colour. It is difficult to predict the colour changes but it is generally expected that an oxidising environment will enhance red and orange colours while a reducing environment will produce dark grey to black. Dark grey to black colours may also be attributed to carbon which is present in fine grained sediments (Winkler 1973: 84Dimes 1990a: 131, Honeyborne 1990: 185).

For example, the laminated gypsum of Agia Triada displays almost all the possible colours that can derive from iron pigments. The peculiar pink gypsum of Agia Triada is one of the most attractive decorative features of the building (see Chapter 3 and 5). Dark grey to deep black gypsum is found in Rooms 17, 8 and the Staircase 61 of Agia Triada as well as at the royal magazines of Knossos and in Magazine 33 at Phaistos. Quite dark gypsum slabs of grey and brown colours are also found at the main hall 2a at Nirou

Khani but the colour here is not as dense as in the aforementioned sites. The initial colour of those slabs was much lighter and in most instances the blackening is a result of carbon originating from the burning of organic matter or by reduction of iron oxides. Especially in the magazines, the black staining of the rock is attributed to the fierce conflagration and the combustion of the olive oil that was stored in them.

2.2 Gypsum as a natural rock

2.2.1 Evaporites

Evaporites, of which gypsum is one, are salt deposits precipitated from saline water, through the evaporation of salt lakes, brines, or inland seas. J.K. Warren (1996) defines as an evaporite a rock that was initially precipitated from a saturated surface or near surface brine, in hydrological systems driven by solar evaporation. Warren's definition includes not only the evaporites of primary deposition but also the diagenetically altered or secondary ones, which constitute the majority of Pre-Neogene deposits.

The evaporites that precipitate from a standing body of surface brine and retain the crystallographic evidence of the depositional process are defined as 'primary evaporites'. 'Secondary evaporites' are precipitated as intra-sediment crystal growths and replacements or cements in pre-existing evaporite or non-evaporite sediments. They are deposited either during primary deposition or later during burial diagenesis or uplift exposure (J.K. Warren 1996).

Primary evaporitic formation depends on the balance of three factors: arid climatic conditions which favour evaporation, fresh water supply by rivers, and salt water supply by straits and marine channels. Evaporitic sediments develop within a wide range of environments, provided that the ionic concentration of the water involved reaches saturation. This can be achieved to a large extent in nature by evaporation, in areas where free circulation is restricted and evaporation exceeds precipitation and runoff for a long time (Schreiber and Decima 1976, Schreiber 1988: 5, Papadopoulos 1994: 267).

In the lakes of internal drainage basins for example, rivers are continually bringing down dissolved salts that are mainly products of the chemical weathering of rocks. Thick deposits of salts are gradually formed and the lake water becomes highly saline (e.g. the Dead Sea). Amongst the most common of them are gypsum, anhydrite and rock salt or halite (Kendall 1988: 13).

Moreover, gypsum occurs widely in desert soils as a result of the evaporation of ground water. Such desert pans can be powdery or compact and massive and they are formed under arid climatic conditions, when evaporation exceeds precipitation. In desert soils gypsum also occurs in crystalline concretions which are known as 'desert rose'.

The range of surface and subsurface settings where evaporite salts can be found are summarised in Table 2.2 (J.K. Warren 1996). Evaporites can flow and back-react so easily that secondary evaporites can be found as syndepositional phases in the primary matrix (as they can dissolve and re-precipitate), while primary precipitation is still in progress. The secondary evaporites have different mineralogy and texture but they maintain the volume of the primary evaporite deposit. The ability of gypsum to dissolve and precipitate is related to the complexity of its mineralogical forms and its vulnerability to weathering. The diagenetic reactions of limestone and sandstone are much slower, which is the reason why they resist weathering better than gypsum (J.K. Warren 1996).

The study of the depositional and diagenetic textures of gypsum can be very helpful in determining its provenance as well as the approximate depth from which it comes. It also provides information about the depositional environment and the stratigraphy of the outcrops and further, the working properties of the stone and the required technology for its extraction and shaping. The morphology of the predominant gypsum textures, which occur in the outcrops of archaeological interest, will be the topic of a separate section in this chapter.

2.2.2 Gypsum and Anhydrite

Gypsum and anhydrite are amongst the first minerals to precipitate when saline solutions are progressively evaporated under natural conditions. As the seawater evaporates the first salt to separate is calcium carbonate. Calcium sulphate appears when the salinity reaches 3.35 times the normal value of sea-water. Thus when sea water evaporates at 30 °C the deposition of gypsum should begin when the brine attains the above salinity, and continue until salinity reaches 4.8 times the normal value, which is the point that deposition of anhydrite begins. Nearly one half of the total amount of calcium sulphate will be deposited as gypsum, until the concentration in which anhydrite becomes stable is reached. As evaporation continues further, halite starts separating with anhydrite, when the water content has been reduced to less than one tenth of the original. Finally, in higher concentrations polyhalite is the next salt to precipitate.

The formation of crystals in solution is a process of nucleation of Ca^{++} and SO_4^{--} ions, which interact to form small particles of $CaSO_4$. Under normal surface conditions gypsum is strongly favoured as the first mineral to precipitate, while in extreme surface temperature and brine concentration, anhydrite can form as a product of primary nucleation (Billo 1986).

Concerning the conditions that determine the precipitation of gypsum or anhydrite, Posnjak (1940) reported that when seawater is evaporating below 42° C, calcium sulphate will be deposited in first place as gypsum. At 30° C, almost one half of all the calcium sulphate present in the original sea water will be deposited in that form, and only when the volume of seawater has been reduced to nearly one fifth, does deposition of anhydrite begin to take place. The temperature of transition of gypsum to anhydrite in pure water is 42°C but is lowered considerably by the presence of NaCl and by increasing pressure. More recent studies suggest higher transition temperatures. It is also affected by the presence of Mg, Na, K sulphates and their hydrates.

The effects of pressure and of different concentrations of halite (NaCl) on the gypsum anhydrite equilibrium temperature have been calculated by Macdonald (1953) (Fig.2. 18). In high concentrations of NaCl in the brine, deposition of anhydrite can take place in quite low temperatures.

2.3 Gypsum textures

Gypsum textures are classified in three categories: i) the primary, ii) the secondary diagenetic and iii) reworked or clastic

2.3.1 Primary textures

The crystal textures of primary evaporitic depositional products depend on the nature and concentration of the dissolved salts and the temperature of the brine. Primary crystals show a variety of habits including long slim prismatic needles, flat lozenge-shaped facets, elongated swallow-tailed twins, lenticular forms comprised of two curved faces or stubby tabulate forms. The most common primary textures are the macrocrystalline and the laminated gypsum (Schreiber 1978, Chiarapica *et al.* 1985).

A. Macrocrystalline or Selenite

Macrocrystalline gypsum consists of aligned bottom-nucleated crystals that form crusts on the floor of the deposition basin. The size of the crystals varies from 0.5mm to over a meter. Massive beds of primary gypsum are formed by successive rows of large vertical crystals, or by layers of smaller crystals (1-2cm), which are arranged in an orderly manner (Schreiber 1978). This texture is termed *selenite* from the Greek word for the moon 'seleni' or *spicchiolino* which in Italian means 'mirror-like'. Both terms have their origin in the reflective (010) cleavage surfaces of the crystals, which are often exposed in well oriented beds. Selenite is usually colourless and transparent but it may be stained with iron oxides. Selenite is also found in marine clays, where is most probably formed by the interaction of the sulphur from iron pyrites on the calcium carbonate of shells (Deer *et al.* 1966, Groves 1958, Shcreiber 1798, 1988, Warren

1996).

Twinning is very common in gypsum crystals and thus the term 'arrowhead' and 'swallow tail' are used to describe such types (Fig.2. 19). Twin crystals are either very pointed, or have a wide re-entrant angle depending on the impurities incorporated (Schreiber 1978: 55-56, 1988: 195-205).

Cody and Cody (1989) have shown that (101) twinning is favoured in the presence of a-amylase, an enzyme, which is excreted into soils and water by bacteria, fungi, algae, and plant roots.

B. Laminated gypsum

Laminated or laminar gypsum is a quite common texture in evaporitic sediments which occurs in beds that vary from 2cm to 1m in thickness. Laminated gypsum can be either pure or layered with carbonates. The laminae are generally thin (1-8mm) and they are parallel, rippled (climbing or oscillation ripples) or cross-stratified, displaying an interesting decorative surface (Fig.2.20) (Schreiber 1978: 47).

These textures are called *marmara* in Cyprus or *balatino* by the Italians and in the geological literature (Pernier 1951:419, Levi 1976:3, Schreiber 1976, 1978, Ciaparica *et al.* 1985, J.K. Warren 1996 etc).

Schreiber (1978:50) notes that the macroscopic and microscopic differentiation between primary and diagenetic laminated gypsum rocks can be very difficult (Fig.2.21a and b). Interlocking reverse graded crystals in the laminae may be considered as a diagenetic feature although no residual anhydrite has been found, as expected in secondary gypsum textures. In the case of Minoan gypsum the distinction between primary and diagenetic features is crucial as it closely relates to the provenance of the stone. As will be shown in Chapter 3, primary gypsum is only found on central Crete and on the east end of the south coast while in the rest of the island and the mainland the outcrops consist of secondary or diagenetic gypsum.

2.3.2 Secondary gypsum

Pre-Neogene evaporites show secondary or diagiagenetic textures which indicate displacive growth, re-crystallisation, back reactions and replacement. When gypsum is buried and temperature rises above 50-60° C, it converts to anhydrite. The dehydration temperature depends on the depth and the salinity of the pore-fluids. If the pore salinity, for example, approaches sodium chloride (NaCl, Halite) saturation, dehydration can occur in shallow depths and temperatures around 40° C. In less saline brine, dehydration will take place in burial depths of hundreds of metres (Murray 1964, Shearman 1966, k. J. Warren 1996).

The most common secondary products of this process are *nodular gypsum and anhydrite* with enterolithic fold and *chickenwire* textures. The anhydrite texture may be pseudomorphous after gypsum (retaining characteristics of the original gypsum morphology). Anhydrite beds, formed after dehydration of gypsum, are often uplifted and subjected to re-hydration and conversion into diagenetically regenerated gypsum. (Murray 1964, Shearman 1966, Shreiber 1978, Warren 1996).

The main products of these burial cycles are the *porphyroblastic* and the *fine grained* or *alabastrine gypsum*. *Porphyroblastic* crystals are coarse, up to 2cm long and they can be euhedral or unhedral, thin acicular or thick stubby and aggregate into centimetre-scale rosettes. *Alabastrine* gypsum on the other hand is fine grained, with crystals less than 50μm and poorly defined crystal boundaries. Alabaster may be pure white, but it is often banded or veined and stained with iron oxides or other impurities (Groves 1958, Holiday 1970, Schreiber and Decima 1976, Kanaris 1989, Lugli 1993).

Excess amounts of trace elements, mainly of strontium and boron, released by the conversion of gypsum to anhydrite, are precipitated in the alabastrine gypsum as celestite, or boron-bearing minerals such as probertite, ulexite, and priceite (K.J.Warren 1996). Identification of such minerals indicates the diagenetic origin of dehydration textures in which they are contained and may distinguish them from the ones deriving from dehydration-hydration cycles caused by firing.

The name 'alabaster', which is used today to describe the white fine-grained massive variety of gypsum, is also of Greek origin. The stone vases known as 'alabastra', however, were usually made of stalagmite. It should be noted that the oriental alabaster is stalagmite too and it should not be confused with the gypsum variety to which the geological term refers (Deer *et al.* 1966, Graham 1962: 144, Shaw 1973: 21, P.M. Warren 1969: 132).

The gypsum variety used in the Palace and the neighbouring 'elite houses' at Knossos is widely known as alabaster. However, the petrographic study of the different gypsum varieties used in Minoan architecture has shown that 'true alabaster' with the geological definition of the term, is not used in Minoan Architecture (see Chapter 3).

Another widespread texture of gypsum is the fibrous one, known as *satin spar,* which is filling veins and fractures of mudstones and shale adjacent to evaporite beds (Warren 1996, Schreiber 1978).

2.3.3 Reworked or clastic gypsum

Reworked and recemented gypsum is also common in large evaporite deposits, generally described as *clastic gypsum*. When surface water salinity is suitable, gypsum crystals can grow on the surface of the brine via solar evaporation, forming crusts along the surface of the basin, which float until they become so heavy that they sink. The crystals then settle at the bottom of the basin, forming a fine-grained bed of cumulate crystals, (*gypsarenite*) or a coarser one (*gypsrudite*). Fluctuations in salinity result also in the formation of *laminated gypsarenites* in shallow basins (J.K. Warren 1996, Schreiber 1978, 1988).

A schematic classification of the predominant varieties based on crystal shape and grain size by Ciarapica *et al.* (1985) has been a mostly helpful guide for the identification and classification of the varieties of gypsum which have been used by the Minoan masons (Table 2.3). The varieties are divided into three categories: A) idiotopic gypsum consisting of well shaped crystals, subdivided in macrocrystalline and crystalline according to the crystal size, B) xenotopic gypsum consisting of non idiotopic irregular crystals and aggregates C) clastic gypsum that consists of re-worked and re-cemented gypsum. The description of thin sections from the outcrops and the sites refers to this classification and Table 2.3 should be the reference for the reader in order to understand the crystallographic differences of the varieties that were chosen by the Minoan builders for each specific architectural function.

2.4 Structure and morphology of gypsum outcrops

The structure and morphology of gypsum beds are some of the most important factors which determine the choice of the quarry location as well as the techniques that used for the extraction of the stone. The predominant structures of gypsum beds according to the classification of (Ciaparica *et al.* 1985), schematically shown in Table 2.4, are: I. massive banks, II. laminations and beds, III. nodular gypsum and anhydrite IV. streaks and boundins and V. other, miscellaneous structures.

Structures I and II are usually of different age from that of the host rock while structures III and IV are formed during late diagenesis by displacement and replacement of carbonate by anhydrite. Gypsum in an exploitable form for structural purposes can only be found in the formations of type I and II.

The gypsum textures that occur in massive banks (type I, in Table 2.4) are:

A). Idiotopic arrow-head gypsum in primary growth (selenite or primary gypsum)

B). Clastic gypsum (gypsarenite, gypsrudite, primary or syndepositional)

C). Re-crystallised gypsum or anhydrite (microcrystalline or alabastrine, formed after diagenesis)

D). Distorted idiotopic arrow head gypsum (primary deposition)

The gypsum textures that occur in beds and laminations (type II in Table 2.4) are:

A). Alternating layers of idiotopic arrow-head gypsum and other material (clays or carbonates), B) laminated gypsum in parallel bedding C) laminated gypsum in cross bedding and D) laminated gypsum in distorted bedding

Nodules of gypsum and anhydrite in the formations of type III are usually not suitable for building purposes due to their limited size but can be used for vases, ornaments and micro-sculpture or for the production of plaster. Material that is found in streaks and boudins (type IV) as well in other miscellaneous structures (type V) usually are not preent in sufficient quantities to be used for building purposes.

2.5 Mediterranean Evaporites

The closure of the connections between the Mediterranean and the Atlantic, known as the Messinian Mediterranean salinity crisis introduced an evaporite deposition environment in the Late Miocene Epoch (Late Messinian). The drastic environmental and climatic conditions led to the formation of several evaporite deposits, predominantly gypsum, in the whole of the Mediterranean. Messinian evaporites are distributed on Central and South-East Crete where the major Neogene gypsum deposits occur.

The wide environmental range under which evaporite formation is possible, has caused some controversy about the origin of the Mediterranean evaporites that were deposited during the Messinian Mediterranean salinity crisis (Shearman 1966, Kinsman 1969, Schreiber and Decima 1975, Schreiber 1988:8, Kendall 1988, Loyd 1972). Three major models have been extensively discussed in the bibliography: A) Deep water, Deep basin model, B) Shallow water shallow basin model, C) Desiccated deep basin model (Loyd & Hsu 1972).

According to the first hypothesis, the deposition of the evaporites takes place in a deep-water environment. This implies that during the time of evaporite deposition the Mediterranean was a deep-water basin not isolated from the Atlantic but separated by a shallow sill. The circulation was sufficiently reduced to cause an increasing salinity, which led to the crystallisation and accumulation of carbonates, sulphates and Halite (NaCl) on the deep basin floor.

The second hypothesis assumes the deposition of evaporite minerals on the bottom of a shallow restricted shelf sea, which may or may not have been connected with the

Atlantic. This implies that the present depth of the Mediterranean Sea has been a result of post - Miocene subsidence, which followed the formation of the Upper Miocene evaporites.

The third model of the desiccated deep basin suggests the deposition of evaporite minerals on inland playas, whose flat basin floors were thousands of meters below the Atlantic sea level. The playas were originated by the desiccation of the late Miocene Mediterranean when it was completely isolated from the Atlantic.

Within the framework of the Deep Sea Drilling project in the Mediterranean, isotopic analysis was carried out in order to examine the evaporite stratigraphy and its genetic significance (see Hsu *et al.* 1973, Nesteroff 1973). The Miocene sulphate samples showed a great variability and no tendency to group near the values of marine derived sulphates. This supports the hypothesis that deposition occurred in a desiccated basin consisting of playas, salt ponds and isolated ephemeral lakes covering thousands of square miles. Fresh water from rain and run off was an important contributor to the basin, as demonstrated by the negative carbon and oxygen isotope analysis of many of the carbonate samples. The desiccated playa environment may have existed as shallow parts of the basin but the rapid appearance over the entire basin of uniform open marine conditions indicated by the Pliocene carbonate isotope values suggests a deep basin deposition (Loyd & Hsu 1972). The Messinian gypsum of Sicily, however, as well as the Cretan ones, show the characteristics of relatively shallow water deposition (Shcreiber & Friedman 1976).

The texture of the gypsum varieties that are available in the outcrops of Crete as well as the structure and the morphology of the outcrops of Crete that and of primary importance in the study of the quarrying and cutting technology have not been studied and therefore there is very little information in the literature that can be used in this study. The Messinian gypsum of Sicily however that has been systematically studied by several scholars (Shcreiber & Friedman 1976, Macaluso and Sauro 1996, 1998, 2001, 2003 and others) offers a good parallel and provides very useful information as regards the properties of the various lithofacies and the weathering of the different varieties.

CHAPTER 3

GYPSUM OUTCROPS OF CRETE

This chapter deals with the gypsum outcrops of Crete and the petrography of the gypsum rocks that occur at the outcrops and of those that were identified at the sites. I will briefly review the geological and archaeological literature on the gypsum outcrops of Crete and describe the characteristics of the two major groups of gypsum deposits; the Permo-Triassic and the Neogene (Messinian). Following that, I will focus on the outcrops that present archaeological interest and the varieties of gypsum that are available within these outcrops. Further, I will describe the varieties that have been used at the five buildings that I studied in detail, as identified by means of petrographic analysis. I will then make an attempt to correlate the lithological facies that were recognised at the outcrops with the Minoan gypsum rocks and to determine their provenance. Finally, I will discuss the provenance of the gypsum rocks from another four sites where only a few blocks of it are present and which were sampled and examined although not recorded in detail.

3.1 Gypsum outcrops as presented in the archaeological and geological literature

Gypsum deposits occur in 59 locations in Greece, distributed mainly in west (Epiros, Aitoliko, Ionian Islands) and south Greece (south Peloponnese, south Dodecanese and Crete). In the north gypsum occurs only in Kavala (Fig. 3.1) (Drougas 1980:23-27). The stratigraphical sequence of Crete indicates that conditions favouring the deposition of gypsum existed in the Permo-Triassic and the Neogene Period (Late Messinian).

Gypsum outcrops have often been mentioned in archaeological reports or marked on survey maps of small areas. The outcrop of Gypsades with 'old gypsum quarries' was first marked by Evans on a general plan of the close vicinity of the Palace (Evans 1928:547 and 1930:192) and since has been mentioned in several archaeological publications as the main source of the Knossian gypsum (Fig.3.2). It has also been marked on the map of the Archaeological Survey of the Knosssos Area (Hood and Smyth 1981).

Hood *et al.* (1964) marked on a sketch map a small outcrop of gypsum on the north side of the hill with the Minoan settlement at 'Trokhaloi' on south coast of Crete and described a second one near Myrtos (Fig.3.3). Warren describes the Myrtos outcrop in a separate note: "On the slopes of the 'Tourli Valley', south of the early site of Myrtos, Fournou Korifi, deposits of gypsum occur, of an entirely translucent glassy variety which peels off in thin layers. It is unlike any of the other forms of gypsum occurring in the island" (Hood *et al.* 1964:99). The same author, in his work *Minoan Stone Vases* refers to 165 gypsum quarries and 10 mines (Warren 1969: 132), as reported in the Rockefeller Survey (Allbaugh 1953:66).

Other gypsum deposits including Phaistos, Agia Triada, the cave of Gortyn, Roufas, and Tsangaraki, have also been briefly mentioned in archaeological reports without any description of the variety of gypsum or the nature and the extent of the outcrop (Pernier 1951:419, Levi 1976:3, Evans 1928:80).

The above information as presented in archaeological studies, whether valid or not, cannot help in understanding the overall distribution of the raw material on the island or how it relates to Minoan sites, since it is scattered and too general to give a comprehensive picture. It can in fact be confusing sometimes, when, for instance the same outcrop is referred to with different names, according to the neighbouring location that is preferred for describing it, or in the case of Warren's reference, which refers to 165 quarries and 10 mines of gypsum instead of "165 (stone) quarries existing on Crete and 10 mines of gypsum in operation" that is referred in the original source (see Warren 1969:132, Allbaugh 1953:66, Gale 1988:62).

As regards the varieties of gypsum it seems none of all the archaeological records up to now have described correctly the varieties that occur at the outcrops and the sites. The description by Warren for the 'translucent glassy variety' at Myrtos apparently refers to selenite but this is definitely not the only outcrop where this variety occurs. On the contrary, selenite occurs in almost all the outcrops of the Knossos area, at Myrtia near Galatas, at Tertsa on the south coast and to a lesser extent at Myrtos.

The most accurate and reliable information about the gypsum deposits of Crete is obtained from the few geological publications (Fytrolakis 1972, Roushy 1982, Dermitzakis *et al.* 1990, Delrieou *et al.* 1993), the geological maps of IGME (Institute of Geological and Mineralogical Research) and in two 'Techno-economical Studies' of the gypsum deposits of the island undertaken by the same institute (Kanaris 1989, Drougas 1980). The IGME maps are now being revised and reprinted in more detail and are expected to be mostly useful in understanding the extent and the distribution of gypsum on the island and the stratigraphy of the formations. However not all of them are available yet.

Besides, the existing distribution maps that are presented in the literature include different outcrops, depending on the special subject and the objective of each report or publication. Outcrops of major archaeological importance such as Phaistos, Agia Triada, and the Gortyn Cave (Labyrinth) are not marked in the distribution maps of technical reports because they are not economically significant.

The most useful map is that of Gale *et al.* (1988:59) in the study of the sources of Mycenean gypsum, where although only the principal deposits are given, they are accurately located and grouped, according to their age. The only brief geological descriptions and schematic stratigraphic columns of some of the Messinian gypsum outcrops are provided by Rouchy (1982), Dermitzakis *et al.* (1990) and Delrieu *et al.* (1993). Sections of some major deposits are also drawn by Kanaris (1989) and Zervantonakis (1977).

3.2 Outcrops of Crete

A primary task of my work was to plot a distribution map of the gypsum deposits of Crete (Fig.3.4) that includes the small outcrops of archaeological importance and incorporates all the information that was gathered from the geological maps, bibliography and my field survey. The following sources were used in the preparation of the map: Zervantonakis 1977, Drougas and Kostantinidou 1980, Rouchy 1982, Gale *et al.* 1988, Kanaris 1989, the Alikianou (1969), Ano Vianos (2002), Antiskarion (1985), Epano Archanes (1994), Herakleion (1996), Ierapetra (1993), Ierapetra - Kato Chorio (1959), Siteia-Dionysades (1959), Timbaki (1984), and Vrisses (1993) sheets of the Geological Map of Crete and the Mineralogical Map of Greece (1964). In Table 3.1 are listed the toponyms of the outcrops that are shown on the map with their age and the relevant bibliographic sources.

The gypsum outcrops of Crete are divided in two major groups according to their age: A) the Permian-Triassic deposits that are stratified in the lower horizon of phyllites - quartzites and form part of the metamorphic series of Crete and B) the Neogene deposits of the Late Miocene (Messinian), interbedded with laminated or homogeneous marls.

A third small group of gypsum deposits is associated with the Oligocene flysch (Fig.3.4). Although gypsum occurs in all these three periods, Anhydrite appears only in the Permian outcrops (Kanaris 1989:8, Drougas and Kostantinidou 1980:29, Fytrolakis 1980:54, Chlouveraki 2002).

A) Permian Deposits

The gypsum of the Permian deposits alternates with layers of dolomite or dolomitic limestone in a sequence with dolomites below and phyllites above, or phyllites on either side. It is found in the lower layers of the Phyllite-Quartzite unit, which comprises the second allochthonus nappe of the stratigraphical sequence of Crete. The Permian gypsum has probably derived from the hydration of anhydrite, which explains the appearance of gypsum in the outer zone of outcrops while the underlying strata consists of anhydrite. The expansion associated with the alteration of anhydrite to gypsum, has caused the fracture of gypsum outcrops as well as of the neighbouring phyllites. Permian gypsum is usually microcrystalline, granular, and white in colour or more rarely with a blue tinge (Fig.3.5-3.6). Anhydrite is macrocrystalline, white with a bluish tinge. The main deposits of Permian gypsum are those of Stomio, Sougia, Rodovani, Elafonisi, Palea Roumata in the west, and Altsi, Sfaka, Chrysokamino, Roukaka (Chrysopigi) and Cavo Sidero in the east. The outcrops of Cavo Sidero and Sfaka, have been extensively exploited and there are only traces of gypsum visible today (Fig.3.4) (Drougas and Kostantinidou 1980:29-31, Kanaris 1989:9).

Although Permian gypsum can provide attractive surfaces, suitable for decorative purposes and outcrop in substantial quantities near major Neopalatial sites it was not exploited at Minoan times. This is evident by the absence of gypsum from archaeological sites such as Mochlos that is located just next to the largest Permian outcrop of Crete and the only that is currently exploited by three different companies. The fractured surface of these deposits can perhaps explain the fact that they were not exploited by the neighbouring Minoan settlements.

B) Neogene Deposits

Neogene gypsum was formed in the Late Miocene Epoch (Late Messinian) when the closure of the connections in between the Mediterranean and the Atlantic, known as the Mediterranean salinity crisis, introduced an evaporite deposition environment in the whole of the basin. Messinian evaporites are concentrated on Central and South-East Crete (Rouchy 1982, Kanaris 1989:7) (Fig. 3.3). The Neogene outcrops that are located near the archaeological sites that employed gypsum in architecture are plotted in the map that is shown in Fig.3.7.

As already mentioned the Messinian gypsum is found in macrocrystalline and microcrystalline varieties. Macrocrystalline gypsum is organized in beds with centimetric vertical crystals (selenite), generally larger at the base, where they can be as long as 50 cm (Fig.3.8-3.9). There are many outcrops of this type of gypsum, the most important being close to Myrtos and north-west of Agios Silas. Smaller outcrops are present along the south coast from Tertsa to the eastern part of Crete, and to the south of Heraklion.

The second type of Neogene gypsum is the laminated microcrystalline (balatino) (Fig.3.10-3.11). It mainly occurs at Agia Triada, Ambelouzos, Roufas and Plouti in the Messara but also in the outcrops of Foinikia, Tsangaraki, Pyrgos and Sarchos to the south of Heraklion to a lesser extent (Drougas and Kostantinidou 1980:31, Rouchy 1982, Dermitzakis *et al.* 1990, Kanaris 1989, IGME G.M.).

Another kind of Neogene deposits which is not mentioned in the bibliography is the chaotic facies outcropping in the Plouti-Moroni area, in the immediate vicinity of Agia Triada and north-west of Agias Silas (close to the village of Drakouliaris). This facies includes blocks of limited scale (up to a few meters in size) of all the previously described Messinian gypsum rocks in a chaotic gypsum matrix (Fig.3.12). This chaotic facies was not suitable for quarrying because of the unpredictable distribution of the blocks and their limited extension. However, Levi used mainly this material for the replacement of the original gypsum remains at the domestic quarter of the Phaistos Palace during his restorations in the 1950s (Fig.3.13) (Levi 1976:3, Chlouveraki and Lugli 2003).

C) Oligocene Deposits

Gypsum of Oligocene age occurs in the upper beds of flysch on the south coast of Crete near Ierapetra in the location of Christos, north of Nea Myrtos, and at Vianos. The outcrops are in general small and not in an exploitable form. The macroscopic characteristics of the Oligocene evaporites are similar to those of the Permian. The gypsum is usually white and microcrystalline (Drougas and Kostantinidou 1980:30). Oligocene gypsum, not surprisingly, is absent from Minoan architecture as its occurrences are quite limited and far from the major palatial buildings of Minoan Crete.

3.3 Outcrops and quarries of archaeological interest: the question of provenance

The provenance of sedimentary stones is always a difficult question to answer since deposition that takes place under similar environmental conditions will often result in the formation of similar sediments. Geological and petrographic parameters such as colour, texture, grain size, and mineralogical composition, are often used to describe the stones used in architecture to correlate them to the possible sources. Isotopic analysis has often been used for provenance studies, mainly of marble (see Walkens *et al.* 1992, Maniatis *et al.* 1995, Lazzarini (ed.) 2000).

Our survey has demonstrated that the same lithological facies are repeated in various outcrops of Neogene gypsum which make it impossible to distinguish between rocks coming from different outcrops. However Neogene gypsum can clearly be distinguished from the secondary microcrystalline gypsum that constitutes the Permian deposits. Diagenetic features which point out the secondary nature of the rock can be recognised in thin section. When we deal with the most characteristic textures such as selenite or alabaster the distinction can be made even macroscopically.

Gale *et al.* (1988) examined the provenance of Mycenaean and Cycladic gypsum by means of isotopic analysis of sulphur and strontium. The analysis is based on the variation in the isotopic composition of strontium in the seawater. The difference in the ratios $^{87}Sr/^{86}Sr$ and $^{34}S/^{32}S$, between Neogene and Permo-Triassic seawater is used to indicate the age of formation of the gypsum which was precipitated from those waters.

Considering that Minoans utilized only the Neogene outcrops of Crete for their building projects, isotopic analysis is not likely to add much on the provenance study of

Minoan gypsum. It is however, an adequate but perhaps unnecessary method for the provenance study of the gypsum found in the Cyclades and mainland Greece, since the only Neogene gypsum formations in Greece are found on Crete and thus samples dated to the Neogene period can certainly be considered as Cretan imports. Gale at al. have shown that the gypsum of Mycenae and Akrotiri is clearly of Neogene age which means that they were brought from Crete, while the gypsum of Tiryns has been supplied by a Permian –Triassic source which could be any of the Ionian Islands, the Peloponnese, or the East and West Crete outcrops (Gale *et al.* 1988).

Apart from the similarity of the evaporitic sequence in the various occurrences of the Neogene deposits there are other problems related to the provenance of Minoan gypsum. First is the lack of archaeological evidence related to the sources (i.e. pottery sherds or other remains of human activity) and, second is the severe weathering of the quarried faces, which makes their identification very difficult, if not impossible. Furthermore, the lack of working marks from the outcrops due to the intense surface weathering and possibly to the technique and the tools that were used for the extraction of the stone, make impossible the identification of Minoan quarrying works at the outcrops. The softness, the cleavage properties and the laminated structure of some of its varieties, allowed qualified quarrymen with good knowledge of the properties of the stone to extract large blocks with minimum use of tools and human effort. It is possible therefore, that not many tool marks were left on the quarried faces in the first place.

The lack of information on gypsum quarrying in the bibliography is not surprising, as the literature on Minoan quarrying and building materials and techniques is quite poor. The most helpful publications on this aspect are the study of Shaw on the materials and techniques in Minoan architecture, published in 1973, and the study of Evely on Minoan crafts, tools and techniques, published in 1993. Shaw provides valuable information and plans of limestone and sandstone quarries, where the works have been identified as Minoan, either from dated finds or because there are no other buildings in the vicinity that make use of the same stone in a later period (i.e. Pelekita, Malia, Archanes). He also gives an overview of the existing knowledge of Minoan quarrying activities and discusses sites of which the date of working is uncertain. Some of the most definitely dated Minoan quarries are the sandstone quarries of Malia (Shaw 1973:35-38), Skaria (Driessen 1983), Pelekita (Shaw 1973:31-32, Papageorgakis *et al.* 1991), Malamoures (Papageorgakis *et al.* 1991) and Mochlos (Soles 1983).

As regards the quarries of gypsum Shaw mentions three: the first one south-west of the Palace of Phaistos, discovered by Pernier and Banti in 1900 (Pernier & Banti 1951: 419) the second, west of the chapel of Agia Triada, discovered by Levi in 1951 (Levi 1976:3) and the underground quarry at Gypsades hill, south of the Palace of Knossos, which was reported by Evans in the Palace of Minos (Evans 1928:140, Fig.71, map opposite page 547, Evans 1930: 192).

The first quarry, at Phaistos, was refilled after its discovery in 1900 and therefore it is not possible to obtain any information concerning the techniques used for the extraction of the stone. Pernier reports that he found Middle Minoan pottery associated with the quarrying operations (Pernier 1951:419).

Similarly, not much information can be obtained from the second quarry at Agia Triada. The quarry was discovered in 1951 to the west of the chapel of Agia Triada along the road that leads to Kalamaki, in the course of the conservation and restoration campaign undertaken by Levi. The search for the ancient quarries was initiated as part of the restoration project with the main objective being the extraction of gypsum similar to the

Minoan for the replacement of the heavily weathered slabs at the palace of Phaistos. Replacement of slabs had already started in previous seasons using gypsum from the area of the Gortyn cave with unsatisfactory results. The location of the ancient quarry was indicated out by the presence of large abandoned blocks that were found in the fields. At the base of the blocks were sherds of Kamares ware that date the quarrying operations to the Middle Minoan period (MMIIA-MMIIB perhaps even MMIII). According to Levi (Levi 1952:321 cited in Shaw 1973:42 and Levi 1976:3) the blocks were discarded by the Minoan masons due the inconsistency of their texture. It seems that Minoan masons preferred the fine-grained white and compact laminated gypsum 'balatino' and discarded the chaotic selenite that occurs in the same outcrop.

Levi's workmen cut the abandoned Minoan blocks in order to obtain new slabs from the compact fine grained parts of the blocks. Further, they quarried the suitable remains of gypsum from the Minoan quarry and they bought the land around it in order to continue their search for most suitable and homogeneous rock for their works (Shaw 1973:42-43, Fig.33, Levi 1976:3-4). Shaw noted that the quarry could still be visited at the time of his publication in 1973 and that he had seen other occurrences of gypsum cut into by the bulldozer that smoothed out the modern road. I visited and searched thoroughly this area that is currently cultivated and covered by olive threes in various field trips with the archaeologist and architect currently in charge of Phaistos and Agia Triada and with Prof. Lugli during our field survey and unfortunately all that can be seen today is a dump with scraps, of laminated and chaotic gypsum around it.

The only information that I have been able to find is based on a series of photos that are available in the archives of the Italian School of Archaeology in Athens and two photos that were taken on the spot by Betancourt in 1983 and which he kindly allowed me to use (Fig.3.14-3.15). It is clear in both these photos that there are quarried faces at right angles and that stone was methodically extracted in blocks. Betancourt's photos show that Levi preserved at least one of the Minoan quarried faces of the outcrop. These photos are probably the last records of this quarry. Is not visible any more and I was told by the guards of the archaeological site of Agia Triada that the remains of the ancient quarry were demolished by a bulldozer that the owner of the land used for cultivation purposes.

The third quarry that is mentioned by Shaw, the underground pit at Gypsades, has also been refilled and the only evidence still visible today is a cavity on the surface. Evans wrote that the opening of large gypsum quarries with subterranean extension was visible on the hill of Gypsades, which implies that it was probably already refilled when he recorded it (Evans 1928: 140 fig.71, map opposite p.547, Evans 1930: 192) (Fig.3.16-3.18). The Gypsades hill has been considered by several other authors as the most possible source of the gypsum employed in the construction and decoration of the Palace of Minos and its surrounding buildings (Graham 1962:4, Cadogan 1992:136, Papageorgakis 1988, 1993, Evely 1993:208). Hood, in the *Archaeological Survey of the Knossos Area* (Hood and Smyth 1981) suggests that the gypsum quarries used in the Bronze Age at Knossos for ashlar blocks, and for floor and dado slabs, probably came from sources near the settlement area. They marked Evan's 'quarry' in the map (Site 303) as well as a second possible quarry location, noticed by D. Smyth in 1977 (Site 345) (Fig.3.19).

There is always a question-mark associated with these suggestions, due to the lack of a systematic comparative study of the petrographic characteristics of the different varieties of gypsum which occur at the Palace, and the material found at Gypsades hill and in the area of Foinikia, Malades and Tsangaraki.

All the publications on ancient quarries of Crete since 1973 give only some general information on gypsum using Shaw as their main source. Dworakowska in her book '*Quarries in Ancient Greece*', published in 1975, notes only the quarries of Gypsades and Phaistos and comments that the existing information is "too meagre to be really useful" (Dworakowska 1975: 80). Waelkens, in his article on Bronze Age quarries and quarrying techniques, allocates a paragraph to gypsum in which he also follows Shaw. (Waelkens 1992: 8) The same is true for Evely's work, *Minoan Crafts: Tools and Techniques*, published in 1993 (Evely 1993: 208).

In all the above studies the outcrops of Myrtos in east Crete, as well as the extensive use of gypsum in the nearby Minoan site of Myrtos-Pyrgos are not discussed, although Shaw refers to the site as the only example where gypsum was used to a large extent in the east.

Furthermore, the recent discovery of the palace at Galatas adds one more site on the distribution map of gypsum usage and one more outcrop of Neogene gypsum in the distribution map of outcrops. Exploitation has again here a local character; a few kilometres away from Galatas there is a small outcrop of gypsum just after the village of Myrtia on the road to Skalani. The outcrop is not marked on the IGME Geological Map and is not mentioned in the literature. It was first noticed by Rethemniotakis and Warren in a field trip in 2003 and was recently brought to my attention by Rethemniotakis

The underground pit of Gortyn, 3.8 km north of the Kasteli village, and also known as the 'Labyrinth', has also been suggested as a possible source of Minoan gypsum. Shaw included this quarry in his section on limestone but thought that it may have served as a source of building material for the nearby Roman city of Gortyn. He notes that the quarry consists of a series of labyrinthine passages, which follow the stratum of usable stone into the hillside (Shaw 1973:39).

The aforementioned petrological and geological study of Dermitzakis *et al.* (1990), presents the same site as a prehistoric one, where "quarrying begins in the MM I period and mainly in the MM III and LM I periods, and is the only underground quarry reported of these periods in Hellenic regions" (Dermitzakis *et al.* 1990:2049). The only reference they give for this information is Dworakowska 1975, who in fact refers to the cave as a place which since the 16th century AD has been considered as a quarry and was described by several travellers. However, she states that "it should be studied (if that is still possible) more carefully, and by modern methods, before its origin and its uses can be retraced" (Dworakowska 1975:16,156).

According to Dermitzakis *et al.*, the gypsum extracted from the cave of Gortyn "has the presuppositions to have been used as a building and/or ornamental stone.....The horizontal bedding and the presence of laminas make possible the separation of flat slabs, while the presence of impressive stromatolites and the various colours, make the stone suitable for decorative purposes" (Dermitzakis *et al.* 1990:2053).

As I have already noted, the samples for the above mentioned study were collected from outside of the cave and the surrounding area since the cave entrance has been closed with a concrete wall for safety. Dermitzakis's evaluation of the outcrop for potential quarrying and the suitability of the rock for decorative and building purposes is quite sensible, but he also suggests a further study of the material in comparison to the gypsum varieties that are found at the Minoan palaces of Crete.

As regards the date of the works in the cave, I do no really know upon which criteria he suggests the Minoan exploitation of the source, but he is definitely not correct. Petrocheilou, who studied and published the cave, suggests that it was not a quarry but probably a natural cave of which the chambers have been enlarged and smoothed by masons. She argues that the same lithological facies can be found outside the cave and in locations closer to Roman Gortyn, and since the worked faces are far from the entrance of the cave, it does not seem reasonable to conclude that the purpose of the works was to produce building stone (Petrocheilou 1985).

In view of the above there is not much known about the Bronze Age quarries of gypsum up to now. The conspicuous need of a well-documented study of the sources and the quarries was recognised as soon as my research on Minoan gypsum was initiated. The utilisation of large quantities of different varieties of the stone at Knossos and Nirou Khani in one broad building period (MMIIIB-LMIA), suggests an organised quarrying system in the Knossos area.

During our field survey on the Gypsades hill in 1999 and 2004 we were able to locate a couple of new locations from where it seems that material has been moved at some point in the past. The new locations LC1 (Fig.3.20) and LC2 (Fig.3.21) were marked in the map of Hood's survey (Fig.3.19). The most suitable beds for the extraction of a large quantity and good quality of selenite with well oriented vertical crystals is area LC2. There is no archaeological evidence for Minoan exploitation of this area or any of the other areas marked on the map, but LC2 shows the structural characteristics of quarried terraces, from where a bulk of at least 1000 (m^3) cubic meters of selenite must have been removed from only one of the two terraces (Fig.3.21). In contrast to the modern quarries where gypsum is extracted for the production of plaster and no attention is being paid to the shape and the size of the quarried stone, the terraces and the vertical faces of the cuts at LC2 are quite even and levelled, which suggest careful extraction of stone for building or decorative purposes. Considering that the only period in the history of Knossos when gypsum was used in such a large quantity is the Minoan, there is a quite good possibility that LC2 was the main source for selenite the extraction of which must have started during the construction of the first palace in the Old Palace period.

Area LC1 (Fig.3.20) may have been quarried some time in the past but stone that seems to have been removed from there is much less and its location is not as convenient for transportation of the stone to the building site.

3.4 Predominant varieties of gypsum as identified in Minoan architecture

The principal varieties of gypsum that outcrop in the vicinity of Minoan sites that made use of gypsum are shown in the details (A,B,C) of the map in Fig.3.22. Petrographic study of selected samples from all the examined sites as well as from Pseira, Palaikastro, Zakros, and Galatas, representative of all the different varieties that have been distinguished macroscopically, as well as from the outcrops that present archaeological interest was carried out by myself at the Department of Earth Sciences of the University of Modena under the supervision of Prof. Lugli.

The study of these samples under the microscope revealed the original texture of the gypsum rocks that were used in Minoan architecture that are often altered due to post quarrying processes and therefore difficult to correlate macroscopically to the lithological fasies that were identified at the neighbouring outcrops. Transformation of gypsum to hemihydrate (and perhaps in some cases to anhydrite) and vice versa has been attested in a great number of samples from the archaeological sites.

Dehydration/re-hydration of primary gypsum resulting in gypsum-anhydrite phase transformations is a common diagenetic process that can also happen naturally in the outcrops. Testa and Lugli (2000) have shown that gypsum-anhydrite transformations have taken place in the Messinian evaporites of central Tuscany in Italy and that amongst the exposed evaporitic lithofacies the only primary texture is selenitic gypsum. Other gypsum textures such as nodular microcrystalline gypsum, gypsarenites and gypsum laminites are secondary and are produced by dehydration of gypsum to anhydrite and successive re-hydration (Lugli 1993, Testa 2000).

However, such diagenetic features do not occur in any of the outcrops that were examined macroscopically or microscopically. Thus it is certain that the secondary textures that have been identified in many of the examined samples of Minoan gypsum are produced by post-quarrying processes and that the varieties that were quarried and placed in the buildings were originally primary.

The predominant varieties of gypsum that have been identified in the examined buildings and their major occurrences are described in detail in the following paragraphs along with descriptions and photographs of the most characteristic thin sections.

It should be clarified here that once the varieties that are available at the outcrops are identified and classified, their recognition at the building can be made by careful macroscopic observation provided that the rocks have not undergone alteration of their structure or suffered severe weathering. The macro-crystalline and crystalline varieties, in particular, can usually be identified even when burnt and weathered. However, Minoan gypsum is often covered with surface encrustations or has been burnt to various degrees and therefore the only secure method of identifying the original variety is microscopic observation of the crystal texture.

3.4.1 Selenite (macrocrystaline gypsum)

One of the most common varieties of gypsum is 'selenite', a spectacular variety of primary gypsum consisting of large translucent crystals that form very attractive reflective surfaces. The crystals may reach a few decimetres in length and are commonly twinned (arrow-head or swallow-tail twins) (Fig.3.23). Selenite rocks are used for exterior as well as for interior architectural elements at Knossos and Pyrgos while at Megaron Nirou and at the palace of Galatas they are found indoors. Three main varieties of selenite were used by the Minoans:

A. Massive selenite rocks

Description

Massive selenite rocks occur in thick beds made of orderly rows of large, mostly vertically standing crystals, up to a few decimetres (Fig. 3.24-3.25). The crystals are translucent and sometimes show a yellowish tinge due to carbonate and clay seams that may be present at the crystal boundaries. When cut parallel to the crystal growth direction, the perfect cleavage plane of the crystals can be displayed providing a highly reflective surface when illuminated directly. The planes that are vertical to the crystal growth show a less interesting surface that is still translucent but not as reflective. Characteristic samples as observed in thin section are shown in Fig.3.26 (SC37) and Fig. 3.27 (SC26).

Occurrences

Outcrops of this variety occur mainly in the area south of Knossos at Gypsades, Malades, Tsangaraki (Fig.3.22A) and Pyrgos (Fig.3.22), at Myrtia north-west of Galatas (Fig.3.22), at Tertsa and at the outcrops east of Myrtos-Pyrgos (Fig.3.22C).

Uses

Massive selenite rocks are used extensively at Knossos for structural and ornamental purposes (i.e. orthostates of the West Façade, large jambs of the magazines, door frames at the Little Palace, the South House and the Royal Tomb), at Megaron Nirou (Rooms 6, 5 and 12) and on a smaller scale at Pyrgos.

B. Banded selenite

Description

Banded selenite (Fig.3.28-3.29) is characterized by relatively small vertical crystals (0.5-2 cm) organized in a few centimetre thick layers. The crystals are usually perpendicular to the bedding and the layers are marked by thin and faint laminations parallel to the bedding. Characteristic sample as observed in thin section is shown in Fig.3.30 (SC41).

Occurrences

This variety occurs in almost all outcrops south west of Knossos (Fig.3.22A) and east of Myrtos-Pyrgos (Fig.3.22C).

Uses

This is the main variety used at Pyrgos for all sorts of functions (Fig.3.29). It is also used at Knossos for functions similar to those of massive selenite but to a lesser extent. The thresholds and the doorjamb bases of the West Porch at Knossos are good examples of this variety but for bulky structural elements such as orthostates, piers and pillar bases massive selenite is preferred.

C. 'Nodular and lenticular' selenite

Description

This rock was described for the first time by Prof. Lugli in the course of the field survey and petrographic study of Minoan gypsum that I carried out under his supervision (Chlouveraki and Lugli 2003). It is composed of centimetric nodular and lenticular aggregates of clear gypsum crystals oriented perpendicular to the module and lens surfaces (Bassetti *et al.*, 2004) (Fig.3.31-3.32). The nodules and lenses of clear translucent crystals are commonly included in laminated fine-grained gypsum giving a general appearance of wavy or 'flaser' stratification depending on the cutting direction.

Small blocks of this material were collected from the outcrop of Foinikia and cut in different directions in order to obtain surfaces parallel to those that have been identified at the palace of Knossos (Fig. 3.33-3.34, 3.36). The surface that is produced when the stone is cut in a direction parallel to the laminations, shows wavy veining that is very close to the surface that is displayed on various wall dadoes in the 'Domestic Quarter and the 'Room of the Throne' at Knossos. On the other hand, surfaces cut vertically to the laminations show the parallel veining that can be seen on the floor of the Lower East-West Corridor in the Hall of Colonnades and various benches. Due to the laminated structure it can be easily cut or split into slabs (Fig.3.35). Characteristic samples as observed in thin section are shown in Fig.3.37 (SC30) and Fig.3.38 (SC36).

<u>Occurrences</u>

'Nodular and lenticular' selenite occurs at the outcrops of Gypsades, south of Foinikia, Tsangaraki, Malades (Fig.3.22A), Agia Barbara (Fig.3.22), Sarchos, and Myrtos (Fig.3.22C).

<u>Uses</u>

This type has been used extensively at Knossos to produce wall dadoes, floor and bench slabs, thresholds, doorjamb bases, the treads of the first flight of the Grand Straircase and even the Throne seat, the earliest preserved chair in the history of Europe (Fig.3.36). It is also found at Megaron Nirou in Hall 2a and at the bench in Room 12. It is commonly not found in outdoors spaces and is rarely used for bulky structural elements.

3.4.2 Fine-grained laminated gypsum or balatino

Description

Laminated gypsum is a fine-grained variety of sulphate rock (gypsarenite and gypsumsiltite) showing thin laminae of carbonate and argillaceous material (Fig.3.39). The variable concentration of thin laminae into the gypsum is the main characteristic that allows the extraction of centimetric- to decimetric-thick slabs in a relatively easy way. The alteration of low concentration of different minerals into the laminae produces a large variety of colours: light green-grey for the relatively pure carbonate laminae, brown to pink-red where amounts of iron oxides and hydroxides are present and dark for the manganese and organic rich laminae. When cut in a direction parallel to the laminations it displays a highly decorative surface with wavy veining while in vertical section it shows mostly parallel veining (Fig.3.40-3.41). Due to the laminations it can be easily cut to in thin slabs. It is often found naturally separated into slabs at the outcrops (Fig.3.42-3.43). Characteristic samples as observed in thin section are shown in Fig.3.44 (SC7).

Dermitzakis *et.al.* (1990) provide a schematic stratigraphic column of the evaporitic sequence of the area of the Gortyn cave or Labyrinth west of Plouti where the upper unit, 20m thick, consists of laminated (balatino) and 'alabastrine' gypsum (Fig.3.45). He describes the laminated variety as fine grained, light coloured whitish to pale pink and pale yellow and in various stromatolite structures, showing in thin section laminae with milimetric alternations of micrite, argillaceous and/or organic material. The entrance of the cave is blocked by a concrete wall and we were not able to observe the stratigraphic sequence as shown in the exposed sections in its interior. However, neither did Dermitzakis, as the entrance was already blocked at the time of his study and therefore the information that he presents is based on observations and samples from the entrance and the surrounding area. The material that we have seen around the entrance is very similar to the material that is cropping at the Plouti area which is also described and mapped by Kanaris (1989:53-54) (Fig. 3.46).

As far as we have seen in the course of our field survey the most spectacular outcrops of laminated gypsum are present in the Plouti outcrops (Fig.3.22B, Fig.3.42-3.43). Smaller occurrences have been attested at the outcrops of Agia Triada (Fig.3.22B) but there is not much to see there today as most of the well stratified and homogeneus material has been extracted by the Minoan quarrymen. Besides, the area of these outcrops is being cultivated and mostly covered with olive trees. Modern exploitation may also have taken place in one of the occurrences (the westernmost) shown in the Antiskarion sheet of the IGME geological map, because we could not find any traces of it at or around the location shown on map.

Significant occurrences of laminated gypsum were also identified near the villages of Sarchos and Pyrgou (Fig.3.22). Kanaris (1989) describes the outcrop and shows in section its two occurrences at Sarchos and Pyrgou that are named by the local people 'gypsokephala' (Fig.3.47). The same outcrop is referred to by some authors as 'Krousonas' (i.e. Zervantonakis 1977, Drougas and Kostantinidou 1980).

Both Drougas (1980:31) and Kanaris (1989:51-52) use the term 'alabastrine gypsum' to describe the rock of this outcrop. Kanaris specifies that it is laminated and similar to the gypsum of Tsangaraki and Foinikia. After macroscopic examination of the outcrop we concluded that there are two major primary textures exposed on the surface: laminated gypsum and 'nodular and lenticular'. True alabaster, meaning the secondary nodular microcrystalline gypsum, has not been found in this outcrop. Kanaris uses the term 'alabastrine gypsum' in the geological maps and sections but in the text he describes the texture of laminated gypsum and refers to the Italian term 'balatino' (Kanaris 1980:57). The term 'alabastrine' is avoided in the present work due to its controversial character.

In the Knossos area laminated gypsum constitutes a large body of the occurrences at the outcrops of Tsangaraki, outcropping mainly at Tourla hill, Mathanes, and around the cemetery of Tsangaraki (Fig.3.22A, Fig.3.48). Smaller occurrences are present at Gypsades around the dump where Evans has marked the 'quarry with subterranean extension'.

In the east, laminated gypsum occurs at Myrtos and to a lesser extent at Tertsa (Fig.3.22C). Kanaris reports that the laminated gypsum constitutes the main body of the Myrtos outcrop and estimates that the approximate thickness of the bed is 20m (Fig.3.49) (Kanaris 1980:57). However, during my field study Lugli and I have located in this outcrop significant occurrences of banded, massive and 'nodular and lenticular' selenite as well (Fig.3.50-3.51) (Chlouveraki and Lugli 2003). The laminated gypsum that I have seen on the surface is quite fractured and does not seem to form beds suitable for the extraction of architectural stone. However, better material might be present under the surface.

Uses

Laminated light brown to pinkish gypsum rock is the most common variety used at

Phaistos and especially at Agia Triada for wall dadoes, floor and bench slabs. Its use for structural purposes is limited to a few pier blocks, jambs and staircase treads. Very little laminated gypsum is found at Knossos and only a single floor slab at the floor of Hall 2 in Megaron Nirou. Laminated gypsum is found at the palace of Knossos as well but not in significant quantity and therefore its presence can be attributed to thick laminations into beds of nodular and lenticular selenite that must have been quarried systematically. Interestingly enough it is absent however from the site of Pyrgos despite its substantial occurrence in the neighbouring hills.

3.4.3 Alabastrine (microcrystalline) gypsum: the effect of fires

The most popular but also controversial form of gypsum is the microcrystalline massive or nodular variety, also termed 'alabaster', when it is snow white or light coloured. Although alabaster is usually thought of as the most widely used variety of gypsum at the Palace of Knossos, petrographic analysis has shown that it is a result of alteration of primary selenitic crystals due to dehydration caused by fire. Alabastrine gypsum is a microcrystalline, usually white, variety of secondary gypsum commonly deriving from the hydration of anhydrite.

According to Dermitzakis at al. (1990) alabastrine gypsum exists in the upper unit of the evaporitic sequence in the area of the Gortyn cave associated with the laminated gypsum (or 'balatino') (Fig.3.32). He describes the laminated gypsum and notes that "some other finer laminaes have diagenetic alterations of gypsum to anhydrite with impurities of clays and iron oxides. This type is called alabaster and is used as an ornamental stone" (Dermitzakis *et al.* 1990:2053). We were not able to find any of this material around the cave but it is possible that diagenetic processes of local character have taken place.

Rouchy (1982) also notes 'nodular microcrystalline gypsum' (gypse nodulaire microcrystalline) in the lower units of the evaporitic sequence of Agia Barbara south of the Herakleion basin (Fig.3.52) but again, I have not seen such a material on the surface of the outcrop and cannot be certain about its form and extent.

It should be reminded here that the term 'alabastine gypsum' that is used by Kanaris (1989) and Drougas (1980) refers to the whitish or pale brown, fine grained laminated gypsum and that no true alabaster (secondary gypsum) is present at the outcrops. Dermitzakis specifies that he has recognised diagenetic features and it is indeed possible that some true alabaster exists in the outcrops of Messara but probably not in significant quantity and form for exploitation.

Detailed geological survey of the outcrops south-west of Knossos, in collaboration with Prof. Lugli, showed that no secondary alabastrine gypsum is present at the immediate vicinity of the site. Besides, the great majority of the 'alabastrine' gypsum from the Minoan sites that I have examined, both macroscopically and under the microscope, show that alabastrine gypsum was formed by burning or heating of the previously described selenite rocks.

The massive white alabastrine rocks typical of the Knossos palace are the result of burning or heating of massive or banded selenite rocks (Fig.3.53-3.54). Transparent selenite crystals turn into white microcrystalline aggregates, called pseudomorphs, which preserve the original shape of the former crystals (Fig.3.55, SC18). Although alabastrine gypsum is present in the Permian evaporites, it can be easily distinguished from a burned Messinian gypsum because it is completely devoid of pseudomorphs of former selenite crystals.

Microscopic observation of a series of thin sections from burnt massive and banded selenite from Knossos (Fig.3.56, SC32 and Fig.3.57, SC 45), Megaron Nirou (Fig.3.58, SC19 and Fig.3.59, SC22) and Pyrgos (Fig.3.60, SC40 and Fig.3.61, SC46) reveals the texture of the former selenite crystals that are pseudomorphosed by white alabastrine gypsum (Lugli 2002, Chlouveraki and Lugli 2003).

The wavy laminated often colourful alabastrine rock that was extensively used in Knossos for wall dadoes and floor slabs, benches, staircases and various other functions restricted to interiors or sheltered areas is the product of burning of nodular and lenticular selenite. The most brilliant example of this variety of gypsum in red-orange hues is found at the first flight of the 'Grand Staircase'. The stone is quite well preserved due to its immediate protection from the rain water despite the fact that for several years it was stepped over by numerous visitors (the domestic quarter was open to the public until October 1992). The treads are cut and placed so that the lamination planes are horizontal thus displaying the 'wavy' veining in reddish-orange colours at the top surface. The colours have probably been enhanced due to oxidation of ferrous inclusions, probably during fire, and the result is strongly reminiscent of the colourful laminated gypsum that is found in Agia Triada. The original macroscopic characteristics of the gypsum here are very similar to the nodular and lenticular gypsum that is found at the outcrops of Foinikia, Tsangaraki and Sarchos. As has been seen in most cases the translucent crystals of the nodules and the lenses that have turned into white after fire can be easily confused with fine grained laminated or alabastrine gypsum.

Because of the small size of the selenitic crystals in the nodules and the lenses it is not easy to observe pseudomorphs with the naked eye. There are only a few examples at

Megaron Nirou in Hall 2 (Fig.3.62) and at Knossos in the North Lustral basin (Fig.3.63) where pseudomorphs are visible in the nodules or lenses of this variety. In most cases the examination of thin sections under the microscope, combined with macroscopic observation of the rock on site, is necessary in order to distinguish between nodular and lenticular and laminated gypsum. Observation of thin sections alone can be misleading since the samples may not include both the laminated and selenitic part of the rock. Quite a few of my samples were described as laminated gypsum or laminated part of nodular and lenticular selenite. For the final identification of the variety I had to return to the sites after the petrographic study in order to observe the macroscopic characteristics of the rocks.

Sampling of *in situ* gypsum architectural elements is also limited by restrictions concerning the size of the sample and the location of sampling. The samples that were taken from the Grand Staircase for example were very small and already loosened although not detached from the treads. As a result the variety was identified as laminated gypsum but was later proved to be part of a nodular and lenticular rock (Fig.3.64, SC34 and Fig.3.65, SC35).

Samples from loose slabs from Megaron Nirou, that were relatively larger, show both textures that identify the rock as nodular and lenticular selenite (Fig.3.66, SC23 and Fig.3.67, SC52).

Various examples of such alterations are illustrated and discussed in Chapter 5 while the dehydration/re-hydration process and its effects on the physical properties of the resulting rock are dealt in more detail in Chapter 7 as one of the most distinctive and extended weathering forms that occurs in the Minoan buildings.

Fine-grained laminated gypsum rocks are normally affected by fire in a less spectacular way. The colour of the rock, especially the pinkish-red, may be enhanced by burning but the macroscopic aspect remains commonly very similar to an unaffected rock. The effect of burning is revealed only under the microscope, where the original granular and prismatic crystals are replaced by cloudy ameboid gypsum (Fig.3.68, SC9 and Fig.3.69, SC10).

Black staining of the surface due to fire has been observed mainly in areas where organic material was present, such as the west magazines at the Palace of Knossos and the storerooms of Phaistos and Agia Triada as a well as in closed spaces with poor ventilation, such as the Dog's Leg Corridor at Knossos. In some extreme cases (Room 17, 8, 61 in Agia Triada) the stain has penetrated the entire section of floor slabs (5-7cm thick). It is mostly attributed to the combustion of oil or other organic products. Examples of the loss of translucency or whitening as well the black staining of gypsum will be illustrated. Both the whitening and blackening of the surface are illustrated throughout Chapter 5 and in Chapter 7.

Galatas, Zakros, Palaikastro and Pseira have only a few blocks of gypsum which present special interest due to the distance of the sites from the sources. The rocks were sampled and examined in thin section under the microscope in order to identify the varieties and to determine their provenance. The macroscopic observation and petrographic study of these samples showed that they all consist of primary gypsum, massive and nodular and lenticular selenites, affected or unaffected by fire. The samples are illustrated and described in Fig. 3.70-3.73).

In Table 3.2 are summarised the conclusions of the petrographic study of sixty-two thin sections of gypsum samples from nine archaeological sites: Knossos, Phaistos, Agia

Triada, Megaron Nirou, Pyrgos, Galatas, Zakros, Palaikastro and Pseira. The unidentified samples consist of mesocrystalline of microcrystalline granular textures and may be part of a laminated gypsum rock but the sections are too small to allow the accurate identification of the variety

3.4.4 Clues concerning the provenance of Minoan Gypsum

In view of the above it is obvious that we cannot locate precisely the Minoan quarries of gypsum, with the exception of Phaistos and Agia Triada, where MM pottery was associated with the worked faces of the rock. But although the quarries remain unknown, the varieties that were utilised by Minoan builders are now clearly understood and correlated to the lithological facies that occur in the outcrops. It is apparent that exploitation of the stone remains local throughout the history of the Minoan palaces. The sites that used large quantities of gypsum are all close to the courses or with in a distance of 10-13 km at most. Knossos, Phaistos, Agia Triada and Pyrgos are located at a distance of 2-3 km or less from the sources.

There is no doubt that the builders of Megaron Nirou and Amnissos obtained gypsum from the outcrops of the Knossos area (the closest source), about 10 km away from Amnissos and 13 from Megaron Nirou. Galatas has obtained its gypsum from the small outcrop of Myrtia about 10 km north of the site.

In the east, Pyrgos also obtained material from the nearest source, the Myrtos outcrop on the next hill. The peculiarity of Pyrgos is that although they had close to hand all the varieties of gypsum that are used at Knossos, they choose a single variety, banded selenite to use throughout the entire project. It must have all been extracted at once from a single spot, but I have not been able to locate this on the outcrop. There are no apparent worked phases or structures that can indicate systematic extraction of stone.

Petrographic study of gypsum samples from Zakros, Palaikastro and Pseira (Table 3.2) has shown that they all consist of nodular and lenticular selenite. The gypsum of Pseira is unaffected by fire and the texture of the rock can be recognised macroscopically, while the gypsum of Palaikastro and Zakros is dehydrated and observation of thin sections under the microscope was necessary for the identification and characterisation of the stone. The most obvious source of this material is the area of Knossos. These are all coastal sites and all have contacts with Knossos in the New Palace period that is the peak of the 'gypsum fashion' in architecture, thus the presence of gypsum is quite significant but not surprising.

Archanes presents a quite interesting case as it may have obtained gypsum from the quarries of Gypsades or may have opened a new one closer to the site i.e. at Tsangaraki or Myrtia. Most of the gypsum that is visible has been probably burnt and is macroscopically white and quite compact. The identification of the varieties and their correlation to the outcrops requires sampling and a more detailed survey of the gypsum outcrops south of Knossos that are closer to Archanes.

A comprehensive and detailed geologic data base including all the Neogene evaporites of the island will contribute to a better understanding of the evaporitic formations and their stratigraphy and it would perhaps narrow down the areas where the above varieties exist in an exploitable form and extent.

CHAPTER 4

QUARRYING, SHAPING AND TRANSPORTATION OF THE STONE

In this chapter I will discuss the technology of gypsum quarrying, cutting and shaping. I will first consider the aspects of Bronze Age quarrying and our knowledge of Minoan quarrying. I will then look into Minoan gypsum production based on the tools and techniques that are available to the Minoan masons and the tool marks that have been identified on gypsum surfaces. Finally I will discuss the aspects of transportation of the rock from the quarries to the building site.

4.1 The technology of Bronze Age quarrying

Quarrying is defined as the systematic extraction of architectural and/or ornamental stone which implies the utilisation of large quantities of stone, considerable labour investment and high organisation and skill. The earliest organised quarrying operations are found in Early Dynastic Egypt towards the beginning of the third millennium BC. The limestone outcrops of the Nile valley north of Aswan were the first ones to be systematically quarried for the extraction of large blocks of stone for architecture. Sandstone was introduced in the Eleventh Dynasty and became a common building material by the Eighteenth Dynasty. Granite, which is the third more frequent type of stone used in Egyptian architecture, was quarried since the first Dynasty and during the Old and Middle Kingdom but its use peaked in the Eighteenth and Nineteenth Dynasties (Forbes 1966:167, Dimes 1990:19, Arnold 1991, Walkens 1992:6).

Soft stones such as limestone and sandstone were normally extracted from open quarries on the top or the front of the hills, using the well known trench technique

(Fig.5.1). The first step of the quarrying process was the preparation of stone beds. Soil and rubble were cleared from the surface in order to uncover the rock bedding. The surface layers of weathered stone would have to be removed until good quality of unweathered material was reached. The top and the front were cut and levelled and therefore the top and the front of the blocks were already roughly cut. When the preparation of the bedrock was completed the sides of the blocks were first separated from the bedding by cutting narrow trenches or channels around them using chisels, hammers and/or picks. The bases were then loosened probably by chisel strokes, often utilising the weakness of the bedding planes. Wooden wedges may also have been employed for this purpose but there is no evidence for their use before the Roman period.

On flat terrain a grid was often laid on the surface to guide the quarrying operations which made possible the parallel extraction of several blocks from the same level. In modern terms this method is known as a pit quarry.

On hillsides the stone was extracted from the front of the bedrock by cutting straight lines in vertical steps (Fig.5.2). The stepped quarries have the advantage of allowing different groups of quarrymen to work on different levels without interfering with each other. Examples of small-scale stepped structures can be seen at the sandstone quarries of Pelekita near Zakros and Mochlos (Forbes 1966:169, Shaw 1973: 30-36, Driessen 1983, Soles 1984, Arnold 1991:27-33, Walkens 1992, Evely 1993:208, Rockwell 1993:156-165).

Underground quarrying is also evident from quite early times in Egypt (i.e. the underground quarries in Tura and Gebel Touch). The quarrymen followed clear beds of limestone by opening tunnels on the slopes of hills or mountains. The tunnels or galleries penetrated up to 200m inside the mountains and reached height around 6m. The technique used for the extraction of stone from underground beds was quite similar to the open air one. The desired stone bulk was first separated from the ceiling of the tunnels by removing material from the top so that a space almost half a meter height was opened. Quarrymen could then work on the sides of the blocks with the trench technique, which was employed in open quarries. The operations progressed from the top towards the base and successive layers of stone were removed until the end of the bed was reached. As the tunnel was extending deep into the hill following the beds of the desired stone, waste columns were left in order to support the ceiling. The technique has been described in detail by Arnold (1991:31-32), and good examples of it can be seen at Agia Irini near Knossos (Shaw 1973:39-41).

Different techniques were developed for the extraction of the harder igneous rocks such as granite quartzite and diorite. Quarrying of the hard stones was performed only in open quarries and consisted in chipping off small flakes of the stone by pounding with dolerite balls of 5 kg approximately, until the sides of the desired block were cut. The base of the block was then separated by hammering tunnels underneath, which was a quite difficult operation. The above quarrying techniques, once established, remained in use without any changes until the Ptolemaic period when the use of wedges was introduced (Forbes 1966:172, Arnold 1991:37).

The same consistency is observed in the technology of Aegean quarrying where the trench technique is used in both open and underground quarrying activities for the extraction of sedimentary stones from the Bronze Age and until the Roman period. The first quarrying operations in the Aegean Bronze Age are found in Minoan Crete along with the development of ashlar in architecture.

The presence of ashlar is the most secure evidence that suggests organised quarrying operations for architectural purposes. The first ashlar appears in the beginning of the Middle Minoan Period and although not many quarries have been identified as Minoan, their appearance and development should be a parallel one. Systematic extraction of limestone and sandstone with the trench technique is evident as well as underground quarrying activities similar to those used in Egypt.

However, neither the development of ashlar nor the Minoan quarrying has been studied in the broad context of the island. Shaw (1973) is the main source of information on Minoan quarrying up to now, while single cases have been studied by Driessen (1984) (Skaria) and Soles (1983) (Mochlos). Walkens (1992) gives a brief overview of Aegean Bronze Age quarrying while Papageorgakis *et al.* (1992) describe the Minoan quarries of sandstone on the east coast of Crete (Skaria, Pelekita, and Malamoures). The need of a comprehensive study on Minoan quarrying, considering the broad context of the island and with reference to the development of ashlar in Minoan architecture, has been felt throughout the present study as one of vital importance. This is however an open field for further research, which requires the contribution of both geology and archaeology in a large-scale project. The present work has been limited to the examination of the Minoan gypsum quarries and the gypsum sources that had the potential to be utilised and may have been so, although no traces of the operations have been identified.

4.2 Technology of gypsum quarrying

An organised quarrying industry involves aspects of specialisation, which can be reflected in the selection of the material which is quarried, the employment of specific varieties for certain architectural functions and the techniques of cutting and shaping. Craft specialisation implies a high degree of skill involved in production and standardisation in the method of production of certain architectural elements. The execution of the works as well as the transportation of the stone over long distances also suggests some degree of organisation in the production and the provision of labour and transport modes.

Graham and Shaw suggested that the systematic quarrying methods used for porous limestone may not have been necessary for the extraction of gypsum since the stone is quite soft (Graham 1962:144, Shaw 1973:43). Wealkens and Dermitzakis further suggest that the raw material could easily have been extracted by means of simple tools for cutting wood, but with out specifying the tools and techniques (Waelkens 1992:8, Dermitzakis *et al.* 1990:2053).

A good knowledge of the physical characteristics and working properties of the stone as well as the tools available to the stone masons is of primary importance for the study of stone working technology. The quarrying techniques are determined by the physical properties of the stone, the structure of the outcrop, and the desired dimensions of the quarried blocks. Thus, the methods employed in gypsum quarrying should vary according to the variety that is extracted.

Amongst the physical properties of gypsum that were discussed in detail in Chapter 2, the ones that determine the quarrying technique are hardness, crystal type and size and the structure of the deposits i.e. the laminations veins allow easy separation of the stone along these planes, while the cleavage properties facilitate the extraction, cutting and shaping of coarse crystalline varieties (Fig. 4.3-4.4).

Minoan quarrymen have definitely extracted stone from different facies of the outcrops, found in various depths. The lack of a detailed geological study and of stratigraphic columns of the evaporitic sequence of these deposits, along with absence of visible quarried faces from the outcrops, makes it very difficult to describe the quarrying operations accurately. Therefore I can only make suggestions based on my field observations and the helpful comments by Prof. Lugli.

The massive and banded selenites of Knossos must have been obtained from surface beds and, due to the large bulk of the material that has been removed, the quarried beds should be visible even if no quarrying marks are preserved. As already mentioned, the estimated minimum volume of material that has been removed from only one of the most likely quarried terraces of the proposed quarry of massive selenite LC2 is at least 1000 m^3, a volume that covers the estimated volume of the rock that was used at the Knossos palace and probably the volume that was used in the rest of the 'elite' houses around the palace (Fig.5.5-4.6).

An anticipated model of quarrying for the extraction of massive selenite from the source LC2 is that of the stepped structure that has been already described and can be seen at Pelekita and Mochlos. The channel or trench method of extraction which is used at Pelekita, Malia, Palaikastro and Mochlos would be sufficient for the extraction of gypsum and there is no reason to consider the use of a different method.

The stone would have been removed in successive terraces, as happened with limestone and sandstone, only that its cleavage properties would have made much easier the separation of the blocks, especially for well oriented selenite which is the main material used for almost all bulky structural elements. It is possible that the cutting of trenches all around a block would sometimes be unnecessary, as the stone could easily separate along planes parallel to the direction of crystal growth. The stone was probably extracted from the front of the bedrock moving inwards in steps (Fig.5.2). For the extraction of large blocks there must have been limitations in size determined by the structure and the morphology of the outcrop i.e. fractures and thickness of bedding layers. Fig.4.7 illustrates a quarry of bedded stone that gives an idea of the possible method of extraction of large blocks such as the massive selenite orthostates of Knossos. The orthostates are placed in the building as found at the bedding which means that the selenite crystals are placed vertically.

There is not great standardisation in the ashlar and therefore it does not seem that the quarry operated as a separate unit that send standardised items to the building sites. Besides, the dimensions of the quarried blocks would have been determined by the dimensions and the structural characteristics of the bedding.

There must have been a close communication between the putative architects and the masons who worked for the extraction of blocks of the desired size and shape. However, we do not know how the work was organised in the building process of the palaces. The relationship between the putative architects, builders or masons and quarrymen remains an open question that requires careful examination of a large number of building and quarrying sites before we are able to make some suggestions.

The blocks may have been further worked on the building site in order to be adjusted to their places. The only features that show some standardisation are those of smaller size: staircase treads, pier and pillar blocks, doorjamb bases and some wall dadoes. The length of the doorjamb bases, though, is dependent on the thickness of the wall or the width of the door and therefore the sizes are pretty standard, reflecting also consistency in the building techniques. The back side of the orthostates and the blocks for ashlar walls is usually rough which implies that the blocks were quarried separately and not cut out of large blocks. Therefore not much attention was given to the rear sides and the work was limited only to the visible surface.

The special preference in colour or other aesthetic aspects would have complicated the problem of quarrying, as colour and grain size are quite inconsistent features. The quarrymen would have to direct their operations towards getting stone with the desired aesthetic and structural properties and in the required size. These preferences may have been the reason for the opening of the 'subterranean quarry' of Gypsades, since the surface beds of the outcrop consist mainly of selenite.

The quarrying site, however, has been back-filled and I cannot be certain about the varieties available in the underlying beds or the method of extraction of the stone. The surface layers consist mainly of massive selenite, reworked gypsarenites with veins of fine grained laminated gypsum and nodular and lenticular selenite. It is possible that larger quantities of nodular and lenticular selenite as well as laminated gypsum are available in larger depths but such a hypothesis cannot be proved unless Evans' 'quarry with subterranean extension' is excavated.

Thick beds of laminated and nodular and lenticular gypsum can be seen at Tsangaraki south of Knossos and west of Juktas, where the entire sequence is exposed. Since these deposits were all formed in the same geological period and under similar conditions, it is expected that similarly large beds exist in the stratigraphic sequence of Gypsades and that the source of the Knossian 'alabaster', that is the burnt laminated and 'nodular and lenticular' gypsum, was the underground quarry that Evans pointed out.

As suggested by the restricted use of these varieties to the most important areas of the buildings, they were probably not readily available in large quantities on Gypsades hill in Minoan times. I have not seen any substantial beds consisting of these varieties on the surface occurrences of this area. Therefore these varieties were either extracted from some depth or were transported from the outcrops of Tsangaraki where the surface occurrences are quite extensive. It is also possible that occurrences that were visible in Minoan times are now hidden due to the change in the topography of the area and the intense cultivation.

At Phaistos and Agia Triada the quarrying operations were probably executed in a slightly different way, as the quarried stone is the laminated gypsum that was given this name by the Italian masons due to its ability to split very easily along the lamination planes. The sides of the stone would have to be cut again but the bottom would easily be separated with some chisel strokes.

At Myrtos-Pyrgos supply of suitable stone in the required size was probably even easier. Judging from the material that is available at the present around the main outcrop and the nature and size of the gypsum architectural members that can be seen on the site, it seems that quarrying operations may not have been necessary. Large, almost rectangular blocks already separated from the bedrock can be found in many locations around the outcrop. They are naturally separated along planes that are parallel to the direction of the crystal growth and due to the relatively small size of the crystals (0.5-1cm) the produced surfaces are quite even. Such blocks could be roughly cut down to the desired size and then moved to the site where they could be further shaped and dressed.

4.3 Tools and toolmarks

In order to be able to understand the methods that were employed in cutting and shaping architectural gypsum we first need to acknowledge the tools that were available to Minoan masons. Both Bronze and stone tools must have been employed in the quarrying, cutting and shaping process. A detailed functional classification of the metal artefacts of the Aegean in the Early and Middle Bronze Age, up to the end of the Prepalatial Period of Minoan Crete, the majority of which continues to be used in the Protopalatial and Neopalatial Periods, is provided by Branigan (1968, 1974). Deshayes's (1959) broader study on the bronze tools in Europe and the Near East also includes the Minoan bronze tools and discusses their function. Further, the tools that were utilised in quarrying and shaping of stone have been described in great detail by Saw (1973:44-75) and Evely (1993:207-217), who outlines the principles and procedures of building construction and provides a very useful model of the Minoan mason's and builder's tool kit along with a chronological table.

Given that the tools and techniques of curving and shaping have only slightly changed from the Minoan period up to now, the study of traditional tools and techniques can be also very helpful in understanding the stone working process. Evely (1993), Rockwell (1988, 1993), and Hill (1990:97-106) have classified the traditional and modern tools that are used by stone masons, many of which are known from prehistoric times. Rockwell (1993) analyses in detail all the aspects of a building project, extending from the extraction of the stone to the finishing and placement of stone on the building. Hill (1990) summarises the methods and the tools used in traditional stone-working and discusses the problems related to their recognition. In Figs.4.8-4.9, are illustrated the Minoan tools that may have been involved in stone working and their chronology as classified by Evely (1993:211, fig.84) and in Fig.4.10 the traditional ones as classified by Hill (1990:101, fig.5.2). The majority of these tools can be used for either wood or stone. A brief description of the tools that have been found in Minoan Crete and are thought to be used on stone and their specific functions is given below.

Adze-Axe: axes and adzes occur in various shapes and they may often be combined in one tool. They may have flat horizontal blades on either side (double adze or hoe), a flat horizontal or vertical on one side and a hammer head on the other, or a flat horizontal and a flat vertical side. Their principal use is for cutting wood but they can also be used for initial roughing out or final dressing of mainly soft stone (Shaw 1973: 48, Evely 1993:56, 75). Axes and adzes or the combination of the two are already introduced from the MMI period but the flat axe-adze does not appear until the Neopalatial period (Shaw 1973: 48, Branigan 1974:22, Evely 1993:72-75)

Pick: The shape of picks also varies. They may have two pointed edges or one pointed and one flat horizontal usually referred to as a pick-adze. Like the axe-adze, the pick or pick-adze does not seem to be essentially used before the Neopalatial period and even then there are not many examples known to us up to now. Although principally employed in agriculture, picks are also used in the stone production process, mostly at the quarries for cutting trenches and separating the blocks from the bedrock. Pick marks have been identified in various quarries including the limestone quarry of Agia Irini near Knossos (Shaw 1973:48-50, Evely 1993:71).

Chisel: Chisels are probably the most abundant bronze tools found in Minoan Crete already introduced in the EMII period. The number of chisels increases greatly in the new Palace Period when all Minoan industries peak. They are usually 27-31cm long with a flat straight or slightly rounded (curved) blade 1-3cm broad (Shaw 1973:60, 71).

Evely (1993:4-19) gives a detailed account of all the types of both modern and Minoan chisels and discusses their use for a number of applications. Apart from carpentry another major application of the chisel is in the stone production industry. The chisel is the most common tool used for shaping, dressing and curving details on stone and its role in architecture is discussed in detail by Shaw (1973:70-75).

A hammer or mallet is used for striking the head of the chisel. Its marks on the stone surface are usually long, contiguous and often overlapping straight grooves. Chisel marks have been identified on Minoan ashlar masonry or other worked architectural members made of limestone or sandstone. Chisel marks are sometimes difficult to distinguish from adze marks although the later are usually broader. Various examples of chisel marks are illustrated by Shaw (1973:71-73).

Point and punch: The punch and the point can be described as chisels with round or square section and with rounded and pointed edges respectively instead of flat. Amongst the applications of these tools is the shaping and dressing of stone. According to Rockwell (1993:40) punches are more suitable for soft stones while points are mainly used for harder rocks. Punches are known from Early Bronze Age Crete and by the New Palace Period they are widely distributed on the island (Branigan 1974: 27, Evely 1993:93)

Hammer: This is the most common tool used for striking chisels, punches or points. Hammers can be made of bronze or stone and weigh up 1-7kg. There are not many hammers known from Minoan Crete and its possible that either mallets or rough stones were also used for striking cutting tools. Examples of bronze hammers from Knossos and Agia Triada and stone ones from Knossos and Gournia, are reported by Shaw, all dated in the New Palace period (MMIII/LMI) (1973:52-55).

Mallet: This is a wooden hammer that is usually quite large in order to have enough weight. Since they are entirely made of wood they are not preserved and therefore their existence and use is hypothetical. Mallets would have been suitable for driving chisels, points and punches. Shaw (1973:52) notes that the use of mallets explains the fact that the edges of many chisels are not blunted.

Mason's saw: Saws for stone cutting are thin metal blades 10-20cm high that can be as long as 5m, and are usually toothless. Toothed saws similarly long are usually interpreted as tools for cutting wood, but according to Rockwell (1993:45-46) they can be used for cutting very soft stone such as tuff. Masons saws are usually two man tools and have two handles, one on each end, or they are set in a wooden frame (Fig.5.11). Sawing with a toothless blade is achieved with the use of water and abrasive sand or powder that is added to the thin path that is cut with the blade. Hand sawing is a time consuming process and the rate of sawing depends on the quality of abrasive and the hardness of the stone.

According to most authors, and to my opinion, the saw is the most probable tool that was used for cutting thin slabs of gypsum for walls and floors. Minoan saws are made of bronze and both types with and without teeth have been found. Evans notes that the most remarkable object in the hoard of bronze objects from the House south east of the South House, dating to MMIII/LMIA, is a bronze toothed saw, 1.63m long whose closest parallels are the saws that were found at Agia Triada, which are also contemporary. Due to the great length of these saws, Evans suggested that they were used for sawing the gypsum slabs that are abundantly used at both sites. He also notes that saws were proved to be very useful in the works of restorations carried out at Knossos, implying that they were used for cutting gypsum slabs, a practice that the

Italians followed some years later during the restorations of the palace of Phaistos (Evans 1928: 632, Figs. 394-395). Another three smaller saws were found in the inner room of the basement of the South House (Evans 1928: 629, Fig.393, d,j,i).

Shaw reports twenty-three saws found in six sites: Knossos, Agia Triada, Mallia, Gournia, Zapher Papoura and Zakros with preserved lengths from 0.28m to 1.70m and thickness ranging from 1mm to 7mm. He argues that sawing would be the only efficient method for mass production of such slabs, although no evidence has been provided by tool marks. Evely presents a more detailed catalogue of all types of saws, toothed and toothless, and includes small saws for carpentry. The saws of Knossos are all toothed while those of Agia Triada represent both types, two are toothless and one is toothed (Fig.5.12). (Shaw 1973:55-669, Evely 1993:26-39). Mason's saws were also used in Egypt but mainly for hard stones such as Egyptian alabaster (calcite) and granite (Arnold 1991:50).

From the written sources of Egypt we know that the bronze tools used for official work were provided by the state and were stored at a state warehouse. Common tools were assigned to individual workmen as their own responsibility while larger specialised tools do not seem to be entrusted to workmen. The tools remained property of the state and were accounted every season (Eyre 1987a:175).

There is no archaeological evidence for such practices in Minoan Crete but perhaps the fact that most of the bronze hoards and particularly specialised tools such as the large saws are not found in ordinary town houses indicate the state ownership on Crete as well. It is quite reasonable that the state would have to provide the appropriate equipment that was needed for the execution of the royal building projects and that there was a control and maintenance of the tools carried out regularly by the officials of the state.

As regards the tools used in Minoan Crete for the extraction of sedimentary rocks, Evely and Shaw refer to picks used for the opening of the trenches at the sandstone quarry of Pelekita and the underground quarry of limestone at Agia Irini. At the latter Evans observed marks of a mason's saw but Shaw has identified only picks and adzes. After the extraction of the stone, further shaping and finishing of the front surface was carried out with points, punches or chisels whilst the rear sides of the blocks often show marks of axes or adzes. For rough shaping, pounding with some short of hammer or a stone pounder, similar to those used in Egypt, has been suggested by Evely. Pounding marks can be seen at the East Facade of Chrysolakkos, at Malia on the lower parts of column bases and on ashlar masonry at Tylissos (Evely 1993:213).

Fine details such as the angular clamp holes were cut with the help of chisels and punches or points, while hand and mason's saws may have been used for small pieces and for cutting slabs and dadoes. The final smoothing or polishing of the front surface was probably achieved by means of grinding stones and some abrasive media, which was also the common practice in Egypt (Arnold 1991:44, Evely 1993:213).

The identification of tool marks on stone surfaces and quarry faces presents many problems. Tool marks are most likely to be found on the unfinished surfaces of architectural stone, which are usually hidden by other elements of the structure and therefore impossible to study. Besides, the marks of different tools are not always clearly distinguishable, and especially on soft stone surfaces such as gypsum where tool marks are not as sharp and clear as they might be on hard stone. Furthermore, as Hill comments 'the difference in the work of two workmen can be greater than the difference between the works of two millennia and therefore one should not rely on tool marks for dating the works' (Hill 1990:100) Evely, in his discussion on the Minoan tool marks, also notes the variety of approaches from different workmen and the consequent diversity in the derived patterns as follows: 'often the artisan preferred to start at one end or corner fanning out from there across the block. Others worked in parallel lines across the depth of the face; yet others approached their work almost haphazardly, creating small areas of scratches from a multitude of directions' (Evely 1993:213).

It is therefore quite difficult to assign a certain technique or a tool to the marks observed on the surface. In Egypt, for instance, where tools marks are evident in many quarried faces of both soft and hard stone and the stone working techniques have been studied more systematically, a chronological development of tool marks can be observed but the evidence is sometimes confusing. However, as in the quarrying methods, a distinction is made between the tools used for the extraction of hard and soft stones (Arnold 1991:33).

After observation of the tool marks on soft stone quarry sites of Egypt, Klemm (1988:42 cited in Arnold 1991:33) suggested that softer copper chisels were used in the Old and Middle Kingdoms while harder bronze chisels were used from the New Kingdom onwards. Arnold (1991:33) on the other hand suggested that pointed stone picks were used for the extraction of soft stone during the Old and Middle Kingdoms while the tools used in the New Kingdom remain unknown. His argument is based on the fact that bronze chisels were already introduced in the Middle Kingdom, and that their marks would have been flat and not pointed as those found on the quarried faces. It is possible, however, that bronze chisels were occasionally involved in the quarrying process for special purposes. Further shaping and dressing of soft stone was carried out mostly with bronze chisels driven by wooden mallets. Bronze saws were used in special cases for finishing the joints of the blocks and grinding stones with some abrasive media, such as quartzite sand was used for polishing the surface (Arnold 1991:41-48).

All the above suggestions are based on the observation of tool marks on sandstone and limestone. There are not many references as regards the tools used for the extraction and dressing of gypsum and is usually assumed that they were the same as those used for other sedimentary stones. Gypsum, however, has some particularities when compared to limestone and sandstone. It is not only softer but also has better cleavage properties. Furthermore, the crystal size varies greatly from one variety to another, which means that different tools and techniques would have to be used for different varieties. The finishing of a fine gained surface would have been different than that of a reflective surface of large selenitic crystals which due to the perfect cleave at one plane and good cleavage at another two planes, easily loose thin plates that cleave off during polishing.

4.5 Tool marks as identified on Gypsum surfaces

Despite the severe deterioration of most gypsum surfaces I was able to gather some information concerning the tools and the cutting and shaping techniques that were used. The evidence comes mainly from Knossos and Pyrgos plus one example from Megaron Nirou. At Knossos, tool marks are preserved on the unfinished surfaces of reused blocks, found mainly in the sheltered parts of the West Magazines and the South Terrace Basement. These include marks from flat and pointed chisels, as well as picks and adzes and punches.

Tool marks and mason's marks are found in all areas where gypsum is found in secondary use, mainly built into walls combined with other blocks or irregular stones. Reused blocks of selenite with tool marks and masons marks are found in almost all

West Magazines (including the early Magazines A, B, C), the Corridor of the Stone Jambs, the east wall of the Long Gallery of the Magazines, the Basement Passage under the Corridor of the Cupbearer, at the South Terrace Basements, the south wall of the Lustral Basin of the Room of the Throne, the north-south axis of the Corridor of the Stone Basin, on the pillar blocks of the West and East Pillar Crypts, and in the South-West Pillar Crypt.

Apart from the reused blocks, tool marks are also found on the front surface of the orthostates that are set against the west wall of the West Magazines and on the side of the large jambs and wall piers in the West Magazines, the Early Passage Way with Protopalatial Magazines and the Corridor of the House Tablets.

Amongst the tool marks that have been identified at Knossos are: pick, axe/adze, chisel, point and punch. I have divided the tool marks in three categories: marks found on blocks that are in secondary use, marks found on *in situ* architectural members and marks of the tools that are used to inscribe the mason's marks.

The tool marks of the first category may have been the result of secondary shaping of the blocks in order to adjust them to the walls they are built in, and therefore not much information can always be deduced as regards the quarrying, shaping and dressing of the stone. The tool marks of the second category, on the other hand, give clues for both the extraction and the shaping of the blocks. In general there is a tendency in the literature to interpret axe/adze and pick marks as work carried out mostly at the quarry while finer tool marks are attributed to the final trimming and dressing of the stone at the building site.

As already mentioned in the previous section, it is difficult to distinguish between flat chisel and axe/adze marks, and often impossible, especially when the marks are closely overlapping. Furthermore, if the chisel blade is not parallel to the surface when it makes a v shaped groove that could be very similar to pick or large point marks. The most representative examples that were recorded are illustrated and described below in three separate paragraphs.

4.5.1 Tool marks on reused blocks

Along both walls of the Basement Passage under the Corridor of the Cupbearer are various blocks of selenite in secondary use that indicate flat chisels and some kind of pointed tool, possibly a point. One of the blocks of the east wall close to the staircase at the north end of the passage preserves clear overlapping marks of a flat chisel, both horizontal and vertical (Fig.5.13). The horizontal marks probably from a flat chisel with a 1-2cm wide blade (Fig.5.14) are arranged in two successive zones and the strokes are very close to each other. The rest of the block is worked in a different way with a rougher chisel or an adze showing almost vertical strokes (Fig.5.15). Since the block is in secondary use it is not possible to assign the tool marks to a single phase of its history. In this case the rough marks probably indicate the first shaping of the block, probably carried out at the quarry with an axe or adze, while the second set of marks suggest a further trimming carried out at the building site with a chisel.

Long and fine parallel marks, on another small block on the same wall, that are quite different and not common on gypsum surfaces, also indicate a flat chisel with a small blade. The strokes start from the corner of the block and extend almost to half of its surface. The rest of the block is only roughly dressed with a different tool. It is not possible to measure the width of the chisel blade because the strokes are closely overlapping (Fig.5.16).

A third interesting block in the same passage is shown in Fig.4.17. Part of the surface is finished and smoothed while the rest carries marks of two or three different tools in two separate areas. One of the tools is most likely a flat chisel with a 2cm wide blade which can be traced on the left group of marks. The same kind of tool, but perhaps not the same item, can be identified on the upper part of the second group of marks on the right. Some unusual and, to my experience, unique tool marks can be traced at the lower part of the second group (Fig.5.18). The latter recall a toothed tool but since no toothed chisels (or claws in modern terminology) are known from the Minoan world we may think that they are sets of point or small chisel strokes. The tool marks are lower than the smoothed part of the surface and it seems that a projecting part of a finished block of which the original function is not recognisable, was cut out in order to be reused.

A few more examples of marks that can identified as chisel or axe/adze are found in Magazines C, I, II,VIII, IX, X, XI and XII (Fig.5.19-4.25) An adze can be more securely recognized and distinguished from a chisel on a reused block in Magazine XII (Fig.5.23). Marks of punch and pick are less common and the most characteristic examples are shown in (Fig.5.24-4.25).

Re-shaping and re-cutting is a practice that has been attested in various reused blocks of massive selenite that were originally placed in structures of the first palace. However, not all of the marks that are illustrated here are products of re-shaping and some of them are quite regular and should be attributed to the rough shaping at the building site.

4.5.2 Tool marks on the rear sides of *in situ* blocks

There are fewer examples of tool marks on *in situ* blocks, most of the exposed surfaces are finished and do not show any traces of the works. Clear marks of a 2.5-3cm wide flat chisel can be seen on the south rear side of the lower block of the north jamb in Magazine III (Fig.5.26-4.27). The marks show two different cutting directions that are crossing in the middle of the worked surface almost at right angle. Similar chisel marks cut in a single direction can be seen on the lower block of the south jamb of the same magazine (Fig.5.28-4.29). In Magazine VIII, the south jamb shows different marks that are not as regular and should be attributed to an axe/adze rather than a chisel (Fig.5.30-4.31). The Magazines between Magazine III and Magazine VIII and north of Magazine XII are not sheltered and therefore no tool marks can be detected on the weathered, mostly dissolved away gypsum surfaces.

4.5.3 Tools identified in mason's marks

The mason's marks that are found in more or less the same areas have all been recorded and are presented and discussed in Chapter 5, within the architectural context in which they are found. We know that mason's marks in Egypt were related to certain work groups and Begg has proposed a similar function for the Minoan marks, as representing teams of workers that were in charge of the construction of certain units of the building (Begg 2004). Hood, on the other hand follows, Evans's idea of the religious or magical character of the mason's marks (Evans 1921:132-135, Hood 1984). The interpretation of the mason's marks is not within the purposes of this work, and although the majority of mason's marks are found at Knossos I have not been able to distinguish marks that are used exclusively on gypsum. I have tried, however, to identify the tools that are used for carving the marks on the surface of the blocks and it is perhaps a quite significant observation that the marks are not always incised on the surface of the blocks with the same tools that are used for the dressing of the blocks. This could be a reasonable argument against Begg's idea that the mason's marks represented teams of workers and in particular the work of those who chiselled the surface of the stones. If that were the case I would expect that the same tool would be used in most cases for both trimming and dressing of the surfaces, and inscribing the mason's marks.

Flat chisel, punch and point are the usual tools that can be recognised mainly on the deeply incised marks which as we will see in Chapter 5 are thought to be an early feature. Fine points were probably used for later mason marks that are lightly incised on the stone surface. Selected examples of clear chisel and punch marks are presented in (Fig.5.32-4.37).

The only other site where tools were identified on gypsum is the Pyrgos country house. The majority of the gypsum architectural members at Pyrgos are found loose and therefore it is feasible to examine both rear and front sides. After thorough examination of a large amount of loose blocks and slabs at Pyrgos, I was able to recognise chisel and saw marks on the rear sides of some slabs (Fig.5.38). These saw marks are the only ones that have been identified so far on gypsum surfaces, and are found on the sides of two slabs. Since the marks are not at the back or front, as would be expected if the slab had been sawn out of a large block (Fig.5.39-4.40), I cannot interpret them as marks of a mason's saw. It is rather possible that a smaller hand saw with teeth was used to trim the edges of the slabs that were first roughly shaped with chisels. A hand saw with a steel instead of a bronze blade was used by the workmen of Levi in the 1950's for trimming the newly cut slabs of gypsum for the restoration of Phaistos (Fig.5.41). Even though not indicative of a mason's saw, these marks are considered very important because it is very difficult to find them preserved on the soft and usually weathered gypsum surfaces. I have made casts of all the fragments and reproduced replicas of all surfaces so that they could be better photographed with appropriate lighting. All the gypsum fragments that show tool marks were collected and hidden in more secure place on site. I have now informed the excavators as well as the local archaeological authority and have suggested that these fragments should be transferred to a museum for storage where they can be protected from weathering effects or any intentional or unintentional damage caused by visitors. The rest of the tool marks are identified as chisel marks and are found on the straight and bevelled sides of the slabs as well as at the back surfaces. Some of the marks seem that are made of the same tool (Fig.5.42, 4.44 a and c).

At Megaron Nirou, the back surface and the sides of nearly 200 loose slabs which have been examined showed no apparent tool marks. Chisel marks were found only on one loose doorjamb base (Fig.5.45). It is clearly demonstrated on this doorjamb base that the rear surfaces, meaning the part of the base that was extending under the floor level was not smoothly finished.

At Phaistos and Agia Triada there are no apparent tool marks, as most of the original gypsum is found *in situ* in primary context and therefore the unfinished sides, where tool marks may have been preserved, are not visible. The tools and the techniques however, will have been adjusted to the physical characteristics and the working properties of the quarried variety of gypsum which differ from those of the Knossian varieties. As already explained 'balatino' slabs or blocks could easily be separated along the lamination planes, probably with the help of chisel and hammer. The planes that are vertical to the laminations, however, would have to be worked with the tools that are used for any other stone but cutting would be easier due to the softness of the material. It is almost certain that the saws that were found in Agia Triada, of both toothed and toothless type, were involved in cutting gypsum slabs as well as for wood.

The interpretation of most tool marks is quite vague but again the information that is provided by the literature on Minoan stone-working is scarce and fragmentary. A systematic and comprehensive study and classification of Minoan tool marks with respect to the kind of stone and its architectural function, supplemented with experimental work with various bronze tools, would contribute greatly in the study of Minoan quarrying and stone-working studies.

4.6 Cutting, Shaping and Dressing

Based on the information that is available in the literature, the evidence provided by the tool marks that are found on gypsum surfaces, and the physical characteristics of the rock that affect workability, I have been able to make some suggestions as regards the cutting, shaping and dressing of gypsum.

The bulky blocks of massive selenite seem to be treated as any other stone. The few pick and axe/adze marks suggest that the stone was first roughly shaped probably at the quarry which made it lighter and easier to carry. Chisels may also have been used at these early stages of the work. Blocks with well oriented vertical crystals could probably be separated easily along planes that are parallel to the direction of the crystal growth. This could be achieved by means of a chisel and hammer in the hands of an experienced and the skilful mason. The surface that is obtained by splitting the stone is quite smooth and even and free of tool marks.

For further shaping and cutting of details such as the projections of doorjamb bases, or bevels and mortises, chisels, punches and points driven by hammers, mallets or even rough stones, were used. The final shaping of the stone probably took place near or at the building site so that the possibility of damage over transportation was minimised. There must have been a kind of workshop organised at an open space near the building site were all the stone work was carried out, but unfortunately there is no archaeological evidence for the existence of such a workshop near the examined buildings. The door and *polythyron* jambs with quite standardised dimensions may have arrived near or at the building site already roughly shaped but the final finishing was probably completed there just before their placement.

Thin slabs could be obtained by cutting larger blocks with a mason's saw. Although there are no evident tool marks, the mason's saw seems to be the only known Minoan tool, which could be effective in cutting large gypsum slabs. There is variation in the width of dadoes in general and it does not seem that there was a precise standard for cutting dadoes. However, the height of the dadoes is standard at 1.95m-2m and the same width is usually repeated three to six times in one room which implies that they were sliced out of the same block. In the Hall of Colonnades, for example, five dadoes are 1.40m wide and another three vary from 1.50 to 1.56m. Similarly, in the Queen's Megaron the width of six dadoes is 1.04-1.09m while the widths of another two are 0.87m and 0.27 and give about the same dimension of 1.14m when added.

The saw blade would sometimes exceed 2m in length if we take into account the widest dadoes that I have recorded. Shaw suggests that the blade would be as long as 2.50m in order to allow enough swing for the cutting motion (Shaw 1973:62).

Once the slabs were cut they were placed on the wall that was already prepared with a clayey mortar. The original mortar is visible in many areas at Phaistos and Agia Triada. The most characteristic example can be seen in Room 45 of the latter where one of the dadoes of the west wall is detached (Fig.5.46).

A smaller hand saw was probably used for cutting larger slabs down to the required size as suggested by the saw marks of Pyrgos and practiced by Levi's workmen. Both toothless and toothed saws could be used for cutting gypsum. Perhaps the toothed saw, although primarily used for wood, would be quite efficient for coarse grained gypsum as well, like the nodular and lenticular and the massive selenite of Knossos and this may explain why only toothed saws that were found at Knossos are of this type.

The saws that Levi used in his restoration campaign at Phaistos in the 1950's had steel blades instead of bronze and were placed in the wooden frames that are shown in (Fig.5.47-4.48). We do not know what kind of installation the Minoan blades were affixed to and they did not all take handles on both edges, so some were intended for one workman. The longest ones have holes at both edges but not a great deal of them is known to us. Levi's equipment was quite simple and the materials required for its installation were all available to Minoans. I can imagine that a quite similar installation could easily be constructed and installed at the quarry or at the building site. The blocks could be sliced at the quarry but the edges would be trimmed on site with a hand saw, just before they were installed. It should be remembered here that the stone is quite soft and when cut in such thin (5-7cm) and large (usually $2m^2$ or more) slabs it can be very fragile and requires special precautions in order to be safely transported.

In smaller buildings such as Megaron Nirou, that were projects accomplished in one phase, observations as regards the use of stone can be more conclusive. The uniformity of the material used for individual rooms and functions suggest that the precise amount of each variety had been supplied from an organised quarry with open works at different beds or from different quarries that produced different varieties of the rock. The similarities in size and morphology of several slabs, the regularity of both front and back surfaces and their even thickness further indicates that the stone probably arrived at the site in large blocks, which were then sliced with a saw into thin slabs. We cannot exclude the possibility that the slabs may also have arrived in stacks already sliced, that were then trimmed down to the required size at the building site. Mason's saws were portable and the masons could carry them and install them at a suitable area near the building where the preparation of the stone was taking place just before its placement in the building.

We do not know much about the organisation of the work at the quarry or the building site, but there must have been different classes of workmen in charge of certain parts of the work. There must have been a distinction between the skilled quarrymen that knew how to choose the suitable stone beds and how to extract blocks of the desired size and quality, skilled masons that were in charge of the shaping and dressing of the stone and those that were only involved in lifting and transportation of the stone to the building site. The qualified masons and quarrymen would probably travel with their tool kit to places like Megaron Nirou in order to execute a building project that was appointed to them by the ruler or the authority of Knossos with raw material provided from the organised quarries of Knossos that were probably in continuous operation serving the needs of various building projects around the palace and occasionally providing small quantities of it for projects at further distances. The high level of organisation that is required for the operation of such projects could probably be achieved only within the broader central administration system that was based at the palace.

4.7 Transportation of the stone to the building site

Large quantities of building stone are not usually moved over long distances in Bronze Age Crete. Exploitation of architectural stone has a local character and the choice of stone often reflects their availability in the region near the building sites. When transport via sea routes was available, however, considerable quantities of stone have been moved from the quarry to the building sites. The gypsum of Nirou Khani has been brought from Knossos (13km), the sandstone of Gournia from Mochlos(15Km) (Soles 1983), while Marinatos (1939) has suggested that the stone used for the building at Tylissos were also transported from Amnissos, although the last hypothesis is not supported by recent studies (Evely 1993:208).

The orthostates of the West Façade of Knossos weigh a total of 77.28 tons (only the outer ones of the double row). The weight of the largest one is about 5.5 tons and the average weight of a bulky structural element such as wall and staircase piers, pillar blocks or jambs is 1.5 tons. In view of the vast weight of these elements, quite elaborate and sophisticated methods of lifting and moving these stones, as well as substantial labour, are expected to have been employed. The average weight that a donkey can carry is only about 100kg. A mule could carry some more weight but again these sizes are not comparable with the required power needed for the movement of such architectural elements. The bulk and the shape add to the difficulty of moving and manoeuvring the blocks. Hoists were definitely installed and used in various stages at both the quarrying and the building site. Various wooden ramps and rollers and perhaps carts would have facilitated the moving and transportation. The use of both man power and of domesticated animals is almost certain. From the Egyptian inscriptions of the Old Kingdom and New Kingdom we know that apart from rafts and boats, that were the most common modes of transport throught the channels of the Nile, oxen and donkeys were often attached to the quarrying expeditions and were used for the transportation of stone (Eyre 1987:11-14, 186).

Evans's quarry with subterranean extension (locus 303 in Hood's plan, shown in Map 3.6) is only 350m away (down hill) from the building site and the transportation of gypsum from that source would not be very difficult. However, as already explained, it does not seem that the massive selenite that was used for the orthostates of the west façade and other structural members was extracted from this area. It seems more possible that the nodular and lenticular selenite and laminated gypsum of the palace, that are much less in volume were extracted from that source while the massive selenite was extracted from LC2, which is almost 1km away from the building site and perhaps from LC1, even further, almost 1.3km away (Fig.3.19).

The transfer of massive and probably banded selenite from the last two locations would have been a quite difficult task but we should not exclude the possibility of moving stone via the Kairatos river. The proposed quarrying site LC2 is located in a quite low and smooth terrain about 200-250m west of the river and at an altitude no more than 50m higher than the riverbed (Fig.3.19). It is therefore quite sensible to reconstruct a transport mode via the river. The consequent debate, though, is whether the river was navigable.

Rackham and Moody (1996:56-57) report a Venetian catalogue of twenty-eight rivers that provided 'abundant supply of water' in the beginning of the 17th century AD of which only four maintain substantial water flow at the present. It is certain that water was more abundant in Minoan Crete than it is today but there is no reference to navigable rivers in the bibliography except for Panagiotakis's suggestion that that the produce of the Pediada may have been transferred to the port of Amnissos with small boats or rafts via the Katreros river which may have been navigable at least for part of the year (Panagiotakis 2004:184).

The Kairatos river must have been perennial, as it is supplied by springs and offered a year-round water supply for the Knossos area (Hood 1971:20, Cadogan 1976:13, Roberts 1981:5, Higgins 1996). However, we lack a detailed study on the geomorphology and the evolution of the Kairatos valley from prehistoric times to the present and the only short reference that exists in the bibliography is negative on the navigability of Kairatos. Cadogan (1992:136) in his section on geomorphology of the Knossos area suggests that the "the river was not capable, at least during the late Holocene (for about 10.000-12.000), of carrying any watercraft including rafts, however, the navigability of the Kairatos and Karteros rivers during part of the year is a question that merits closer examination. It is possible that the river could carry rafts during the months of high precipitation and that the Minoan masons took advantage of it and transferred raw materials and agricultural pastoral products via the river at certain periods of the year.

If we accept that the water level was sufficient enough to carry rafts loaded with heavy stone architectural members at certain months of the year then the problem of transportation of the stone would have been less complicated. The blocks could have been transferred from LC2 to the Kairatos River with the help of hoists, wooden ramps and rollers and then loaded on rafts and floated to the closest place to the building site, south east of the palace. It is perhaps not accidental that, apart from LC2, the possible quarrying site LC1 is also located next to the bed of the Vlickhia stream that is a confluent of the same river. Even if the river had not been navigable, a transfer route along the river would probably be the smoothest land root for travelling and transferring materials. Moreover, via the same route, through or more likely along the river, the stone could have been transferred as far as the port of Knossos and from there to the different sites that make use of it on the north and east coast.

A quite large body of workmen would also be necessary at the building site in order to move and place the blocks into the correct position as pointed out by the architect. We can easily imagine such an operation in Minoan times being not very different from Evans's operations in the beginning of the last century. Fig. 4.49 shows a characteristic photo where Cristian Doll, Evans's architect, is supervising the repositioning of the landing block of the fourth flight of the Grand Staircase (Brown 1994:98, fig. 52a and 52b). There are at least twenty-three people involved in lifting and moving the block that must weigh up about 2tons calculated from the dimensions that are given in the drawing that is illustrated in the same photo.

The question of transport modes for such bulky and heavy stone blocks has always been the challenge in stone studies and has certainly occupied my mind from the very beginning of this research. The above proposed route seems to me quite reasonable as it combines minimum labour and safe transfer with low incident of accidents. Even thin sawn slabs could be stacked on rafts and transferred quite safely, although the *in situ* cutting and shaping of such fittings is more probable.

Further evidence, will hopefully be obtained by modern research methodologies for a more accurate and better documented reconstruction of ancient routes and transport in the Knossos area. The current archaeological survey of the Knossos area by T. Whitelaw, E. Gramatikaki, J. Bennet and A.Vasilakis is expected to give more information as regards the evolution of the landscape, the raw material sources, the routes that linked the palace with the sources and possibly the navigability of Kairatos and its confluences.

CHAPTER 5

THE ARCHAEOLOGICAL EVIDENCE

In this chapter I will present the archaeological evidence that has been considered in the study of the use of gypsum in Minoan architecture during the New Palace period. I will first describe the gypsum remains that can be seen at the sites today, focusing on their function and macroscopic characteristics that are closely related to the petrography of the stone with an attempt to suggest provenance and to distinguish between the gypsum of the Old and the New Palace Period when possible. However, it is not within the purposes of this study to verify the chronology of all the architectural gypsum of the palace, neither is it possible to achieve such a purpose without the intensive collaboration of scholars that have studied the pottery and the architecture of the building. Further, the lack of chronological plans of the palace has made very difficult and time consuming even the rough division between the Proto-Palatial and Neo-Palatial gypsum.

In this chapter I have also made an attempt to gather all the relevant information that is published in the final publication of the sites. In the text are often cited catalogue numbers and the plans and drawings on which the architectural gypsum members have been recorded. The plans and the drawings are presented in Appendix 1. The reader can easily locate the numbers on the plans using the description of function and location as a guide. However, catalogue numbers are used in the text mostly for significant architectural elements and it is not necessary for the reader to search for them in the plan as most of those are shown in photographs. For further information such as dimensions, variety, function, preservation the reader should refer to the catalogue that is presented in Appendix 3.

5.1 Knossos

The catalogue of the architectural gypsum of Knossos consists of 2.185 entries. The gypsum remains of the palace were mapped and registered on Hood's plan (Hood 1981) while those of the first floor of the Domestic Quarter were mapped on Doll's plan as published by Evans (1921: 329, Fig. 240). Additional elevation sketches of the walls were drawn in my field notebooks in order to register the stones that are not visible on the overview plan (Appendix 1, Plan 1-12 and Drawings 1-20). For the descriptions of the rooms I use Evans' names including in parenthesis the numbers assigned by Hood in his plan.

It is apparent that most of the gypsum is concentrated in the central section of the east and west wings of the palace (Fig.5.1). Due to the complexity of the building and its chronological phases, which are still subject of controversy, it is not always possible to assign gypsum elements to a certain building phase, but for the volume calculations I have considered that the Residential Quarters, the 'West Magazines' and the 'Throne Room Complex' were all paved and lined with gypsum in the same broad period as part of a large building and refurbishing project that took place in MMIII (Macdonald 2002) or the MMIII/LMIA transition (Niemeier 1994:83-84). Some of the visible remains of the West Magazines are dated by Halager (1977) to the LM III Period but earlier gypsum floors of the first phase of the New Palace Period exist under them. Niemeier (1987) also post-dates some of the gypsum in the Throne Room Complex' but that does not change the broad picture as regards the use of gypsum in the New Palace Period. On the other hand the bulky structural elements such as the orthostates of the West and South Façade, several pier blocks and large jambs throughout the palace were considered by Evans as parts of the Old Palace as laid out in the MM IB period (Evans 1900, 1921). The use of structural gypsum in later periods is not excluded but if we accept that the same basic layout of the Palace was maintained and that the major bulky lower courses of ashlar, piers, pillars and jambs were kept and rebuilt above that means that the majority of the structural gypsum dates to the Old Palace Period and that very few blocks were added in the succeeding rebuilding/refurbishing phases of the building in the New Palace period (Macdonald 2005). In addition there are various blocks of gypsum in secondary use, built into the walls of the West and North Magazines, the South Terrace Basements and spread around the south and north part of the palace, which probably belong to the Old Palace as well, before the MM IIB, referred to as MMII at Knossos, destruction. Although these have all been marked on the plan and the most significant ones have also been registered in the catalogue, they have not been included in the calculation of the total volume of gypsum in the palace. The most significant ones have been roughly drawn in the field notebook (Appendix 1, Plan 1-2 and Drawings 1- 5).

Distribution of gypsum in the Palace

When approaching the palace through the West Court the first architectural gypsum elements that attract attention of both visitors and scholars are the great selenite orthostates of the **West Façade** (Fig.5.2). Evans and later other scholars suggested that the layout of the West Façade and its gypsum orthostates belonged to the Old Palace Period. He argued that by MM IB the original plan of the west side of the Palace had already been laid down and was maintained through out the whole existence of the later palace (Evans 1900:64, 1921:131, 1928:665-667, Hallager 1977:43-45, Warren 1987, Macdonald 2005). This ultimately implies that the selenite orthostates belong to the Old Palace period and that major gypsum quarrying site/sites were already in operation at the time. Although scholars such as Shaw (1973:88, f.n. 8, 1983) and Neimeier (1994), have suggested that the West Façade belongs to the New Palace period (end of MM III), after examination of the petrographic characteristics of the stone and the cutting and shaping technique that was used I tend to agree with Evan's earlier chronology. It seems to me that these architectural elements can be grouped together with all other evidently early gypsum blocks that are found in the palace, and were probably products of the same quarrying project that took place in the Old Palace period. The consequent question the answer to which will confirm such a hypothesis is whether there are any features that may distinguish them from the architectural gypsum that is lavishly used in the major rebuilding/refurbishing of the building in the New Palace period.

The orthostates are set on a projecting course of limestone blocks that Evans called a 'plinth' and will be called here after a '*krepidoma*'. They were placed on the façade so that the visible surface is perpendicular to the bedding and parallel to the crystal growing direction, thus displaying the long side of well oriented crystals that is actually the direction to which the massive vertical selenite is found in the outcrop. The glass-like surface of the crystals would have reflected the sunlight, creating the sparkling effect of a gem stone. This spectacular effect would be seen from far away as it does today in the outcrops where fresh faces of the stone are exposed (Fig.5.3). The selenite orthostates have now lost their glory due to the alteration of their original macroscopic characteristics as a result of a dehydration process caused by fire, which will be discussed in chapter 5.

The lower part of some of the orthostates still preserves their initial crystallographic characteristics and shows a transition line from unburned to burnt material that continues from one block to another. Such transition lines have been observed in several cases in the building. The fire patterns indicate that during the main destruction phase the collapse of the building preceded the conflagration and thus the lower parts of the 'West Façade' and other parts of the building were covered by non flammable building materials such as wall plaster, stone, mud brick, which prevented the direct exposure of the stone to fire and consequently its dehydration. On the orthostates of the façade, the best example of such a transition from burned to unburned or affected to unaffected gypsum can be seen on the corner of the first projection of the façade from the south (Fig.5.4). The remains of the last projection, although poorly preserved, are also unaffected by fire and show the original stone in a more weathered state (Fig.5.5).

Evans and Fyfe saw the stone of the orthostates as a quite weathered white alabastrine variety of gypsum similar to marble, and so did all archaeologists including myself until the beginning of the present research, when the Italian geologists Dr. G. Testa and Prof. S. Lugli pointed out to me the pseudomorphs of the original primary gypsum or selenite. Evans and Fyfe distinguish between the gypsum used in the palace and the adjoining houses and evaluate that of the palace as a higher quality one. Fyfe specifies that the coarse crystalline variety that is found in the houses is only limited in very few parts of the palace like the large blocks with 'bird's mouth' angle of the 'North East Veranda' (Evans 1900:53, foot note 1). It is obvious that they did not notice the continuation of the transition line from one block to another, which clearly indicates that this is a post quarrying alteration and that the material was originally very different as regards its macroscopic characteristics.

The façade was restored by Evans up to Magazine XIV, but presumably the orthostates would have extended to the end of the limestone blocks of the *krepidoma* in front of the Magazine XVI. Under and in front of the *krepidoma* at that end, there are large selenite blocks that are completely unaffected by fire. The underlying blocks are also set on an earlier similar course of smaller limestone blocks and it is apparent that they are somehow earlier than the West Façade (Fig.5.6). Immediately after the end of the *krepidoma*, there is a course of partly burnt selenite blocks with the same north-east orientation set on a lower level (area 57 in Hood's plan). As indicated by the fire marks on their surface that are not consistent along the wall, the blocks are either in secondary use or at least some of them were moved from their position after the fire and were placed back in a reversed position (Fig.5.7). This could have happened some time during the occupation of the building or in modern times during Evans' restoration. Whatever the case is, the blocks are very similar to the orthostates of the 'West Façade' as regards the variety and the shaping of the stone and are most probably contemporary.

The '**West Porch**' at the south end of the West Façade is the main entrance to the building that leads in the palace via the 'Corridor of the Procession Fresco'. The porch, clearly of monumental character based on the remains visible today, did not take its final form until the New Palace Period. There is evidence for the existence of an earlier porch connected with a narrower entrance passage and most probably contemporary with the orthostatic wall of the façade (Evans 1928:667 Fig.425, 427) According to Evans it was renovated after the MM IIIB period presenting "a truly grandiose aspect as seen from the West Court" (Evans 1928:674). Thus the visible remains that have been recorded and calculated in the total volume of gypsum in the building belong to the New Palace period.

The roof of the porch was supported by a single wooden column set on a round selenite base (*KN*4) about 1.35m in diameter of which almost 40% is preserved. The selenite is affected by fire except for part of its outer surface that can be seen on the east side, (Fig.5.8-5.9) where the restoration mortar has been removed. A course of selenite orthostates that continues the West Façade formed part of the east wall, while on the west wall, also set on a projecting course of limestone blocks, are another two orthostates (*KN*1-2). They are mostly unaffected by fire and although quite weathered and dull, they show the original crystallographic characteristics of the material and are very close to the original appearance of the orthostates of the façade (Fig.5.10, Appendix 1: Plan 1, Drawing 1).

Gypsum walkways under the sheltered porch lead the visitor to the entrance of the **'Reception Area' (12)**, the **'Warder's Lodge' (13)** and the **'Corridor of the Procession Fresco'** that leads to the interior of the palace (Fig.5.11). The large doorjamb bases and the threshold of the entrance are made of banded selenite that is placed so that the direction of the crystal growth is horizontal. The westernmost doorjamb base (*KN*6) shows clearly the transition of burned/unburned material and is perhaps the clearest example in the entire palace that illustrates the effects of fire on selenite. The wooden door frame that stood on the base left a clear white mark on the selenite surface. It can be seen as an L-shaped white area that corresponds to the part that was in contact with the burning wood. The rest of the base that was built over with non flammable materials, presumably a rubble construction, remained unaffected by fire and preserves its initial crystallographic characteristics (Fig.5.12). The selenite ashlar blocks of the wall that divides room 12 and 13 (*KN*40, 41) show similar fire marks with a characteristic alteration of the outer surface that was exposed to the fire whilst the upper surface, that was built over, remains unaffected (Fig.5.13)

The slabs that paved the threshold of the entrance are also made of banded selenite that is placed in the same direction as the above mentioned doorjamb base, in a manner that displays again the most reflective face of the stone that is parallel to the direction of the crystal growth (Fig.5.14). Although the original slabs of the threshold are preserved *in situ*, only a few traces of gypsum are preserved at the walk ways of the West Porch and of the **'Corridor of the Procession Fresco'**. Most of them are restored in concrete and therefore it is not possible to describe the varieties with certainty. However, the few remaining traces of gypsum that are preserved (fragments of two slabs: *KN*18 and *KN*36) consist of burnt selenite with an average crystal size of 1,5cm. They are similar to the slabs of the threshold and display the same reflective surface. A third slab that is preserved and visible at the porch (*KN*38) made of 'nodular and lenticular' gypsum was almost certainly placed here in the course of some restoration campaign, perhaps by N. Platon, as it resembles the material that is used for the replacement of the slabs in the main corridor of the West Magazines in the Lobby of the Stone Seat and the Ante-Room of the Throne (Fig.5.15).

Presumably the corridor was illuminated by lamps that would create a magnificent effect when reflected on the gypsum surfaces. Evans' stratigraphical tests in the corridor showed that an earlier corridor with the same orientation existed in the Old Palace Period (Evans 1928: 667-669, Fig. 425). The earlier corridor was narrower and paved with gypsum slabs from wall to wall in contrast to the new one that is visible today where gypsum slabs 1.02m wide, are set in a row at the centre of the corridor and are flanked on either side by schist slabs framed with red painted plaster.

The walls of the earlier corridor were also dressed with gypsum dadoes the lower remains of which were found by Evans and are shown in (Evans 1928: 668, Fig 425). In the New Palace period, the east wall of the porch and corridor was decorated with bull frescoes and the eponymous Procession Fresco. A somewhat misleading and over-elaborate reconstruction of this entrance by Newton was published in the Palace of Minos (Evans 1928: 677, Fig. 429).

The corridor originally extended all the way to the south-west corner of the palace, where it changed direction and continued on an east-west axis parallel to the South Façade. At the height of the South Porch the corridor turn north and led into the Central Court. However the south-west corner of the corridor as well as the part that runs along the south side and the south-east corner are not preserved. Evans has reconstructed only the last part of the corridor that opens in the Central Court. It can be assumed that the corridor was paved with the same materials in its entire length but no suggestions can be made regarding the gypsum variety that was used or the consistency in using the same variety for a single architectural feature such as this long running corridor.

Below the present wooden walkways at the **south-west corner** of the building, are several abandoned selenite blocks that most probably belonged to the collapsed south west corner of palace (*KN*68-81, Appendix 1: Plan 2, Drawing 2-3). They are all made of selenite and some of them have been partly burned showing clear transitions of material affected/unaffected by fire (Fig.5.16). The crystallographic characteristics are very similar to those of the selenite orthostates of the West Façade. Furthermore, the same technique was used in quarrying and cutting of these blocks that always display on their vertical surfaces the long side of the crystals. As explained before this means that the horizontal surface of the blocks is parallel to the stratification of the bedding while the vertical side is parallel to the direction of crystal growth. These blocks could have been extracted from the same outcrop and during the same period with the great orthostates as part of a large quarrying project that was initiated on the Gypsades Hill in order to provide stone for the construction of the palace. However, we cannot exclude the possibility that similar blocks were extracted from the same outcrops in different chronological phases.

Several selenite blocks (*KN*81-90) are also in secondary use built in the south wall of the **'Magazine of the Inscribed Vase' (3)** below the south west corner of the palace. Reused selenite blocks are also found in the room under the **'South-West Columnar Chamber' (4),** mostly burnt, and in the south wall of the **'South Terrace Basements'** where the mortises of the upper surface of a block can be seen as well as mason marks of a double axe with stem (Fig.5.17-5.18).

The reused orthostates and ashlar blocks here, show great similarity in the size, the variety of gypsum that is used, the crystal size, cutting direction, and the tool marks that are preserved on the surface, indicating that the bulky structural elements of gypsum with deeply cut mason marks such as the doorjambs of the West Magazines or the blocks of the pillars in the Pillar Crypts that will be described below, could date to same building period, which according to Evans is the Old Palace Period. Various selenite blocks or fragments of blocks often burnt are found in secondary use in the niches of the north wall of the 'South Terrace Basements' one of which in the east niche, carries another double axe mason's mark without a stem that is considered as an early feature (Evans 1921:132-135, Hood 1987, and Macdonald 2005). Apart from the mason's mark, tool marks from flat chisel (2,5cm long) vertical to the crystal growth direction, are apparent on the surface of blocks in the middle and the west niche.

A little further to the west there is a narrow corridor, the **'Basement Passage under the**

Corridor of the Cup Bearer' (10), which leads to the **'South Propylaeum'** through a staircase at its north end (Appendix 1: Plan 2). Along both sides of the corridor there are various selenite and banded selenite blocks, which preserve very clear tool marks on their visible surface that are presented and discussed in chapter 3. At the end of the staircase there is a large block (*KN*206) that consists of selenite with mostly vertical crystals and is completely burnt. Turning left and then back towards the south is the threshold and the stepped doorway of the **South-West Columnar Chamber (4)**.

The doorway was probably more of a passage, as indicated by the absence of the projections that would hold the wooden door as observed on the typical L-shaped doorjambs (Fig.5.19). The bases (which could also be called piers since they are not really doorjambs (*KN*201 and *KN*202)), the treads of the two steps (*KN*203 and *KN*204) and the adjusting threshold (*KN*205) are made of selenite. It is quite interesting that the crystals are used vertically on the piers and the threshold and horizontally on the steps (Fig.5.20). It seems that Minoans preferred the most reflective face of the stone for the front surface of orthostates, piers and doorjambs. Presumably the column base in the middle of the room as well as the jambs of the east doorway towards the 'South Propylaeum' would also be made of selenite but are now reconstructed in concrete.

The majority of the **'South Propylaeum'** is also reconstructed but few structural elements such as column bases and doorjambs are partly preserved (Fig.5.21). In the east doorway of the pier and door partition, the two L-shaped doorjambs (*KN*191 and *KN*192) are made of selenite that is entirely burnt. The same material is used for the threshold (*KN*197) that is burnt as well. The middle and the west jambs of the partition that are reconstructed in concrete were originally made of gypsum.

The only other gypsum remains in the South Propylaeum are: the column base (*KN*187)

(Fig.5.21 on the left) that consists of a burnt banded selenite, the slab fragments that are set on a concrete base in front of the west wall pier (*KN*188) and those embedded in concrete on the east end of the first step (*KN*189). The slab fragments are made of 'nodular and lenticular' gypsum that is cut in a direction parallel to the laminations except for one fragment that is cut in a perpendicular direction. However, these have all been set in concrete and although there were probably found in this area they are not in their original position.

Immediately west of the South Propylaeum there is a quite complicated multi-period area the so called **'Early Magazines'**.

At the entrance of **Magazine A (17)**, there is a selenite doorjamb (*KN*210), placed horizontally, with fire mark on the upper surface area that was in contact with the wooden frame of the door. The entire doorjamb is exposed and thus the whole base is visible, as extends under L-shaped part that of the doorjambs that we usually see above the ground. It is clear that the L or T-shaped doorjambs are in fact small rectangular gypsum blocks, of which only the upper part that projects above the ground was cut to the shape of the wooden frame that was placed above, provided also with one, two or four projections depending to the position of the doorjamb (Fig.5.22).

A series of selenite blocks (*KN*211-*KN*217) are built into the wall that divides Magazine A from Magazine B (18). Only the top of those blocks can be seen but they form a wall that extends 1m under the ground level, and most of them are about 1m high, as revealed by the excavation of MacDonald in 1987. They date to the MM IB period, and probably constitute part of an Old Palace structure. The selenite is placed horizontally and is partly affected by fire (Fig.5.23 and Appendix1: Plan2).

In **Magazine B (18)** and along the passage to Magazine C, there are again various burnt or partly burnt selenite blocks (*KN*1711-1724) that are set in a quite confusing arrangement and are definitely in secondary use. It is quite interesting that the ones that are built into the east wall (*KN*1720-1724) are mostly unaffected by fire. Two of them have double axe mason's marks (Fig.5.24). A little further to the north is one of the few large blocks (*KN*1718) that are made of 'nodular and lenticular' gypsum of which the outer surface burnt to white (Fig.5.25). It should be stressed here that this variety is used mainly for ornamental purposes and rarely in construction. Along the passage from Magazine B to Magazine C there are more selenite blocks partly affected (*KN*1713-*KN*1715) and unaffected (*KN*1711), again in secondary use.

In **Magazine C (19)** gypsum is used in a similar manner, with various selenite blocks in secondary use (*KN*1705-*KN*1708, *KN*1710) (Appendix 1: Plan 3). A deeply cut '*cross paté*', or '*croix pommée*', mason's mark can be seen on a block of the south wall and a 'window' on a block of the north wall just next to the large jambs of Magazine I (Fig.5.26).

From Magazine C, we enter into the **Corridor of the Stone Jambs (21)** just before the 'Long Corridor (or Gallery) of the Magazines' (40). In the south wall of the corridor there are two blocks of selenite in secondary use, both burnt, one of which carries a '*cross paté*' mark (Fig.5.27). Along the east wall there are another ten blocks of selenite in secondary use that are mostly burnt, apart from two that are built in the lower part of the wall, which are only partly affected by fire (Fig.5.28). They both carry '*cross paté*' or '*croix pommée*' mason's marks. The same mason's mark is found on another block at the north end of the wall. A double axe without stem is also carved on the surface of a long block built in the middle on this wall.

West Magazines

On the west wall of 'Corridor of the Stone Jambs' start the great gypsum jambs of the West Magazines that are aligned along the west side of the **Long Corridor or Long Gallery of the West Magazines (40)**. There are sixteen doorjambs, each of which consists of two courses of selenite blocks that carry mason's marks on their front surface and are mostly burnt (Appendix 1: Plan 3, Drawing 14-15). The height of the jambs is fairly standard; the lower ones being 0.75-0.81m and the upper ones are about 0.60-0.65m high. Their width however varies from 1.10m to 1.58m. The selenite is mostly placed vertically but the crystals are not always well oriented and do not have a consistent crystal size. Such variations in crystal size and orientation are quite common within the same outcrops, as can be seen at the nearest outcrops of the at Gypsades hill.

It is worth describing in some detail the use of gypsum in this area since almost half of the bulk of gypsum that is used in the construction and decoration of the palace of Knossos is found in the West Magazines and is itself more than the gypsum that is found in any of the other sites. Furthermore, most of the mason's marks and the tool marks that have been recorded in the course of this study come from this area.

The architectural gypsum of the magazines represents all periods of gypsum usage in architecture, from the Middle Minoan (orthostates, jambs, ashlar blocks in secondary use) to the end of the Late Minoan period (floor and cist slabs) and bears important evidence as regards the conflagrations in the storerooms that were associated with major destructions. Finally, the weathering effects of both outdoor and 'sheltered' environments of exposure are represented in the 'West Magazines'. Magazines I-VII and XIII-XVIII are exposed to an outdoors environment except for the entrance of the first two which is reconstructed and roofed over with concrete slab. Magazines VIII-XII and the part of the Long Gallery in front of them are also reconstructed and roofed with concrete slab that forms part of the Piano Nobile above.

According to Evans, the large jambs that form the entrance of the corridors of the West Magazines are contemporary with the orthostatic wall of the West Façade that belongs to the earlier Early Palace (Evans 1921:448- 4462). These jambs are all made of selenite that is very similar to the stone that is used for the orthostates, although their present appearance might be somehow misleading due to severe conflagration and natural weathering. The alteration of gypsum is in some cases so severe that even Evans did not identify the stone and referred to it as "massive limestone antae consisting of two high blocks with a continuous reveal to catch a wooden framework" (Evans 1921:461).

After the major destruction in MM IIB the magazines were rebuilt, incorporating in their structure significant quantity of reused gypsum piers, jambs and ashlar blocks that can be seen along the south and the west walls of the corridors (Evans 1921:461). In MM III a series of floor cists, intended for storage of valuables, were constructed in the series of magazines from Magazine IV to Magazine XIII and the Long Gallery in front of them. The sides of the cists are lined with gypsum and often covered with an additional sheet of lead. The entrance of the magazines was narrowed with the addition of new doorjambs and at the same time a wall was added at the end of the third magazine that controlled entrance to the block of magazines that contained the cists from the south. The north end of this block that formed the so called 'Palace Treasury' is confined by the staircase opposite Magazine XIV.

At the end of the Middle Minoan and towards the beginning of the Late Minoan Period the cists of the magazines were converted to superficial vats and by the end of the Late Minoan period they were paved over. The low doorjambs that were added to narrow the entrances of the magazines were also paved over and Mackenzie's tests in Magazines XII and XIII that are still visible today showed that a new gypsum floor pavement was laid over the old and concluded that this took place at the same time that the cists were covered. He also concluded that the gypsum dadoes of the walls were removed at the same time and replaced by painted stucco (Mackenzie 1923).

Hallager (1977:31-35) post-dates these modifications to the beginning of the LM IIIA period, implying that the visible pavements of the magazines belong to the Mycenaean era of the Palace, as clearly stated by Evans in one the first reports of his excavation (Evans 1900:64).

Evans found lots of the cists uncovered, the edges of the surrounding floor slabs broken and in some instances the entire lining was missing, and assumed that this was the work of treasure hunters shortly after the final destruction of the palace (Evans 1921:449-462).

Based on the above information I can suggest that the entire magazines were dressed in gypsum during the New Palace period, including floors, walls, cists and all structural elements that already existed. The floor and cist slabs of three magazines X, XII and XIII were catalogued piece by piece while the rest were only measured as total floor and cist area and the volume of gypsum was then roughly estimated. It was not possible to make detailed observation and record of all the magazines due to the poor lighting in the restored corridors and to the presence of series of large pithoi that obstructs the full view of the walls and makes very difficult, some times, impossible the measurement of the slabs. However the most significant observations are presented below.

Magazine I

The south jamb of Magazine I is the first large jamb in the Corridor of the Stone Jambs (*KN*1703-1704). Each of the two selenite blocks carries two mason's marks. There are two '*cross paté*' on the upper one and a 'gate' and a 'cross' on the lower. They are both burnt and the upper part is stained black (Fig.5.29). Several selenite blocks in secondary use are built into the south (Fig.5.30) and the north wall (Fig.5.31). The lower part of the blocks is unaffected from fire up to an average height of 50cm while the upper part is burnt. Along the south wall (Fig.5.30) there are two blocks with deeply cut 'cross' mason's marks and tool marks (Fig.5.32-5.33). Along the north wall (Fig.5.31) and close to the entrance there is 'window' mason's mark (Fig.5.34) and a '*cross paté*' on another block towards the end of the corridor. The later also is marked by interesting broad tool marks. On the west wall of this magazine start the orthostates that are set against the whole length of the west wall of the magazines and form the back side of the orthostatic wall of the West Façade. The orthostates are very similar to those of the West Façade. They have the same height (about 1.10m) but not the same width. The crystals of stone are placed mostly vertically. The first orthostate as well as part of the second are visible on the west wall of this magazine. They are set on a *krepidoma* of which the first stone is a selenite block that is totally unaffected by fire. They also are mostly unaffected by fire except for a small area on their upper part. The second orthostate (the northern) has a large and quite well finished 'double axe' mason's mark (Fig.5.30). It is a common observation in the magazine corridors and the Long Corridor of the Magazines that the lower part of selenite blocks remains unaffected. It seems possible that the lower part of these walls was still covered by wall plaster remains at the time of the last conflagration. Presumably the upper part of the wall plaster detached and collapsed first and then the fire that followed affected only the parts of the blocks that were directly exposed to it. It is should be noted here that although the entire orthostates are cracked the upper part that has been subjected to dehydration/hydration cycles suffers by dissolution in a greater degree than the unaffected part. This is a quite significant and common observation throughout the palace and will be discussed in Chapter 7.

Magazine II

The selenite blocks of the second magazine (*KN*1701-1702) carry the following mason's marks: a deeply cut 'gate' and a more lightly curved 'cross' on the lower and another deeply cut 'gate' mark on the upper. The weathering of these blocks is very similar to that of the first jambs. They are totally burnt and the upper part is also stained black (Fig.5.36). The south and the north wall of the second magazine are also very similar to those of the first corridor that was described above. Various reused selenite blocks are built into to both walls which at the lower part of the wall are mostly unaffected by fire. Tool marks and one 'cross' mason's mark are preserved on the surfaces of some blocks (Fig.5.37). The orthostates that are set against the west wall of the magazine and they present quite interesting and characteristic fire marks and weathering forms. They both have double axe mason's marks and it is mostly interesting that the north and the south wall are built against them and cover their edges (Fig.5.38).

Magazine III

The south jamb of the third Magazine (*KN*1699-1700) has two large 'double axe' mason's marks one on each selenite block. Both blocks are burnt with black staining only on the upper part and are similar to those that were described above (Fig.5.39). Selenite blocks in secondary use are found again on both south and north walls of the magazine (Fig.5.40). Various tool marks can be seen on the surfaces of these blocks and on the sides of the jambs of the entrance. A 'window' mason's mark is also found on a block towards the end of the south wall and two deeply cut 'double axes' without stem are found on the north wall towards the entrance (Fig.5.41). Two selenite orthostates are set against the end of the south wall and another two against the west wall (Fig.5.42). The transition line between affected and unaffected stone is just a few centimetres above the base of the orthostates and continues from one to the other suggesting that almost the entire room in that side was in fire at least once in the history of the building. Evans has marked two 'double axe' mason's marks that can barely seen today (Evans 1921:449, Fig.322). Remains of both lime stone and gypsum slabs are apparent on the floor of this corridor in contrast to the previous one were there are no visible remains of paving (Fig.5.43). The remains of the gypsum slabs are embedded into concrete, burned and stained black. The rest of the floor is reconstructed with concrete that is divided into rectangular slabs imitating the original floor pavement. The surface of gypsum remains is about 2cm lower than the surface of the concrete around it suggesting that it has dissolved down to this level since Evans' restoration campaign in 1929 or the later conservation and restoration campaigns of N. Platon.

Magazine IV

The south jamb of the fourth magazine (*KN*1697-1698) is exposed to an outdoor environment and therefore is not as well preserved as the ones that are described above. The lower part that is unaffected by fire is in a relatively good condition while the rest of it is poorly preserved due to the action of rain water (Fig.5.44). There is a 'double axe' mason's mark on the upper block of the jamb but it is not clearly visible due to the severe weathering of the surface. The doorway is narrowed by the later addition of a limestone jamb that is of similar shape and size. The south and the north walls are similar to those of the magazines that have been already described (Fig.5.45). There are three 'double axe' mason's marks on selenite blocks, one on the south wall and two on the north. The orthostates of the west wall are burnt except for a small area near the base (Fig.5.46). Evans has again noted two double axe mason's marks in front of these magazines in the same plan of the west section of the Palace. The floor of the magazine was originally paved with gypsum slabs, some of which are still preserved. Along the length of the corridor there are six cists that are all lined with gypsum slabs that are made from both selenite and 'nodular and lenticular' gypsum. The missing parts of the floor pavement and the cist lining have been filled in with concrete mortar as everywhere else in the palace. The original floor slabs are made of selenite, not well oriented crystals and are entirely burnt and stained black. In the middle of the magazine around the third cist, the floor slabs are stained black and the stain extends to the wall. The third cist is also totally stained black and it seems that the stain is associated with the combustion of the contents of the cist and the pithoi that were found next to it (Fig.5.47). Evans suggested that the stain was caused by the combustion of oil. In the first volume of the Palace of Minos he published a photo of this magazine (Evans 1921:458-459, Fig.329) and considered the conflagration in the cist and the staining as evidence of the maintenance of some of the cists as oil vats until the final destruction of the palace. Evans mistakenly refers to it as the sixth magazine both in the text and in the photograph (perhaps a printing or typing error). There is no doubt however that the photo as well as his description of the conflagration and the evidence for the use of the oil vat until the final destruction refers to this magazine (IV) and not to Magazine VI. It is true that in this magazine the lining of the first cists is burnt and stained mainly on the upper and most severely that of the third cist. In the last two cists only the upper part of the lining is burnt white, while the lower half remains unaffected by fire. As observed in many other cases there is a remarkable difference in the state of preservation between the affected and the unaffected part of the slabs (Fig.5.48).

Magazine V

The south jamb of this magazine (*KN*1695-1696) is also as heavily weathered as the one described above in Magazine IV (Fig.5.49). There are no visible mason's marks and the upper block is stained black (Fig.5.50). The entrance of the magazine was narrowed by the later addition of a wall and a new limestone L-shaped doorjamb base. Along both south and north walls are various selenite blocks in secondary use that are all burnt and heavily weathered. There are six cists along the floor of the magazine and one is built in the south wall. The cists are all lined with selenite slabs that are all burnt and only partly preserved. The cist of the south wall is built with selenite blocks rather than slabs (Fig.5.51). The selenite blocks of the cist are burnt and although their outer surface is incised by dissolution flutes, the surface of the interior that is protected from the rain water is well preserved. A 'double axe' mason's marks are curved on either side in the interior of the cist (Fig.5.52). The orthostates of the west wall are made of vertical selenite with large crystals up to 4-5cm and are only partly affected by fire (Fig.5.53). They show interesting weathering pattern quite similar to that of the orthostates in Magazine II (Fig.5.38). Evans has reported one double axe mark in front of the west wall that is hardly visible today. The floor was originally paved with gypsum slabs of which there are only a few remains while the rest is restored in concrete. The original remains of the slabs are made of selenite part of which, under the pithos at the south west corner, is affected by fire.

Magazine VI

As in the previous magazines, the south jamb of the sixth magazine (*KN*1693-1694) is heavily weathered due to dissolution and the upper block is stained black (Fig.5.54). There is a double axe mason's mark preserved on the surface of the upper block. Several selenite blocks are built into the south and the north wall, one of which in the south wall has another 'double axe' mason's mark (without stem). They are all burnt and heavily weathered (Fig.5.55). At the west end of the south wall there is an orthostate that corresponds to the side of the second projection of the West Façade. In Evan's plan a double axe is again indicated in front of the orthostate that I have not been able to locate (Evans 1921:449, Fig.322). The lower part of the south orthostate is unaffected by fire and the transition line between affected/unaffected stone continues on the orthostates of the west wall (Fig.5.56). The paving of the floor is mostly reconstructed in concrete. Original fragments of the floor slabs that are embedded in the concrete consist of both selenite and 'nodular and lenticular' gypsum. There are seven cists along the corridor that are also dressed with both selenite and 'nodular and lenticular' gypsum. Characteristic example is the seventh cist in which the north and the south lining slabs are made of selenite while the east and the west are made of 'nodular and lenticular' gypsum (Fig.5.57). The lining of the first is totally stained black, while in the second third and fourth cists the stain is limited at the lower part of the lining (Fig.5.58). The lining of the fifth cist is not stained but is burnt and heavily weathered while the lining of the sixth and the seventh is only partly affected by fire at the top.

Magazine VII

The south jamb of this magazine is also heavily weathered and stained black (*KN*1691-1692). A shallow, 'star' mason's mark is only partly preserved on the upper block of the jamb (Fig.5.59). Two L-shaped gypsum doorjamb bases were added to narrow the doorway in the New Palace period or later. They were then paved over by the latest gypsum paving that is partly preserved at the present. The Magazine contains seven floor cists that were probably all lined with gypsum slabs although there are no traces preserved in the fourth and the fifth (Fig.5.60). Both selenite and 'nodular and lenticular' gypsum are used for floor slabs and for the lining of the floor cists which are all affected by fire and stained black in places. The orthostates of the west wall are also burnt and stained (Fig.5.61) as are the reused blocks of selenite of the south and north walls which are heavily weathered and do not preserve any characteristic features apart from a 'double axe' mason's mark that is found on a block to the north jamb of the entrance. A 'double axe' mark is also pointed out by Evans in the same plan that was mentioned above (Evans 1921:449, Fig.322). In this area there is also very interesting evidence of conflagration in different chronological phases that demonstrates the potential of a systematic mapping of fire marks on architectural gypsum with respect to the different building phases (Fig.5.62). It seems that at the time that the L-shaped doorjambs were close to fire the side of the north large jamb was covered with plaster that prevented its dehydration. The gypsum floor paving that is above these doorjambs was also burned at a later phase but the lower part of the gypsum jambs still remained unaffected, while the upper part is all affected showing clear pseudomorphs of large selenite crystals (Fig.5.63). It is apparent that the wall plaster collapsed during a fire destruction that was associated with earthquake. The lower parts of it remained *in situ* covering the gypsum of the jamb and the wall. It is not possible to attribute this event with certainty to the first or the second fire based only on the dehydration patterns of a single architectural feature. However, a close observation and recording of such features throughout the palace can contribute to a better understanding of the nature and the extent of the destructions that are indicated by the stratigraphic evidence.

Magazine VIII

This is the first of five magazines (VIII-XII) that were roofed over by Evans and therefore all the architectural gypsum is preserved in a much better condition, similar to that of the first three magazines which are also roofed. The blocks of the south jamb (*KN*1689-1690) are both marked, the upper with two stars and the lower with one. They are the widest jambs (1,54m) along with those between Magazine X and XII (1,58m) (Fig.5.64). The light in the roofed magazines is very poor as the only sources are the small sky windows plus the entrance and thus is difficult to make detailed observations on gypsum surfaces. In addition, parts of the south and the north walls are hidden by pithoi that are standing against them (Fig.5.65). It is obvious, however, that the preservation of the material is far better than it is in the outdoor magazines and that there are various tool marks preserved on the surface of the blocks. There are orthostates against the wall that have double mason's marks incised on their surface according to Evans note on the plan mentioned above. The fire marks in front of this magazine are quite interesting. The floor slab in front of the south jamb is only partly affected by fire while the front surface of the jamb behind it and the traces of a wall dado that was set against it are entirely burnt showing clearly that the floor slab is of later date (Fig.5.65).

Magazine IX

The upper block of the south jamb (*KN*1687) of this magazine has a star incised on its surface while the lower one carries marks of a pointed tool (*KN*1688). Part of the lower block is hidden behind a pithos and therefore I cannot be certain that there is no mason's mark in the hidden area. Evans has marked a 'star' in front of this jamb in his plan of the West Section of Palace in (Evans 1921:149, Fig.322). In the same plan he marked a 'trident' in front of the orthostate of the west wall. In addition to the poor illumination in the magazine, there is a series of pithoi placed along the south and the north wall and therefore it is very difficult to make observations on the reused gypsum blocks, the orthostates or the paving slabs. However the majority of the latest paving is preserved as well as the lining of the cists (Fig.5.66).

Magazine X

The south jamb of the tenth magazine (*KN*1685-1686) is again hidden behind two pithoi that are placed in front of it, but a partly preserved 'star' mason's mark is visible on the upper block and a second of the same kind on the lower one (Fig.5.67). The walls and the floor of the magazine are very similar to those described above. The varieties of gypsum that were used in this magazine were mapped in a draft sketch in the field notebook as well as the major weathering forms and the concrete restorations (Fig.5.68, Appendix 1: Drawing 17). The same sketch includes the catalogue entry numbers of all gypsum elements apart from the blocks that are built in the walls in secondary use. The unaffected selenite was then considered as a different variety of stone than the affected one. It was only after the petrographic study of the material that I understood the alteration in the macroscopic characteristics due to fire and therefore was able to recognise the true varieties of gypsum. It is now clear that the three different varieties that were marked in the sketch, variety 3, variety 2 W/G and variety 1Tr are all selenite of different grain size of which the later (1Tr) is unaffected by fire. The selenite slabs of the floor are all burnt and stained black in the areas that are marked with green colour. The transition line of affected - unaffected selenite that can be seen on the orthostates of the west wall (*KN*1623-1624) is similar to what has been described in the previous magazines with the lower part being the unaffected one. Both orthostates have star marks incised on their surface (Fig.5.69). On the lower part of the wall near the entrance there are remains of the plaster that covered the walls and that is the most probable reason for the preservation of unaffected by fire stone on the lower parts of the wall as has been seen through almost all magazines (Fig.5.70).

Magazine XI

The blocks of the south jamb of this magazine (*KN*1683-1684) are the widest ones (1,58m) and are both incised with a 'gate' mark (Fig.5.71). The dimensions of this and the next three magazines XII-XIV are also longer than the previous ones, as the length corresponds to the third projection of the West Façade. These magazines contain nine floor cists, two more than Magazines VI-X and three more than Magazines IV-V. There are three selenite orthostates, one against the south and two against the west wall which seem to be totally burnt. The south and north walls are of the same character as those that have been described above. The gypsum of the floor pavement and the lining of the cists is well preserved and some of it, near the entrance, is also unaffected by fire (Fig.5.72). The lining slabs of the first and the second cists is completely unaffected by fire and preserve the only tool marks that have been seen on slabs at Knossos.

Magazine XII

The blocks of the south jamb of the twelfth magazine (*KN*1681-1682), about 0.5m less in width than those of the previous magazine, they carry tool marks on their surface and the upper one is incised with a double axe mason's mark that is not very well preserved. Observation is also obstructed by a large pithos that is placed in front of the jamb (Fig.5.73). The gypsum of this magazine was marked and numbered on a draft sketch in the field notebook (Fig.5.74 and Appendix 1: Drawing 16). The magazine is constructed in the same way as the previous ones with a great deal of reused selenite blocks in the south and north walls. Tool marks and mortises are visible on the selenite blocks of the south wall, while most of the north wall is hidden behind a row of pithoi that are placed in front (Fig.5.76). An unusual mason's mark that is found on one of the selenite blocks of the south wall is a rectangle divided by three vertical lines (Fig.5.75). The orthostate of the west wall is broader than the usual. It is just 0.5m high while most orthostates are about 1.10m. In front of it there are remains of gypsum wall dadoes (*KN*1556-1557) that are probably contemporary with the latest gypsum pavement. On the floor of the magazine there are parts of an earlier gypsum pavement exposed in two sections that are marked orange in Fig.4.74. The slabs of the earlier floor (*KN*1567-1570) are made of selenite that is burnt and stained black while the slabs of the later floor, which Hallager (1977) places in LMIIIA rebuilding activities, are not all affected by fire and some of them are made of 'nodular and lenticular' gypsum. The cists are lined with slabs that are locked together in their corners with a fitting cut. The third and the fourth cists (from the entrance) are also lined with a sheet of lead. The lining of the first three cists is totally black while in the others is either white with some black staining in places.

Magazine XIII

From Magazine XIII and onwards the building remains are exposed to an outdoor environment and the preservation of gypsum is quite poor. Details such as tool marks and masons marks are rarely preserved. The blocks of the south jamb (*KN*1679-1680) that are partly covered by the restoration structure above are in a much better condition than those of the north jamb that are exposed to the rain. The upper block has a 'branch' mark incised on its surface that is barely visible, while the lower one has two 'gate' marks. On this jamb one can observe the difference in the state of preservation between sheltered and unsheltered gypsum. The side that is exposed to rain water shows deep dissolution flutes while the sheltered side of the same block is stained but preserves its original surface (Fig.5.77). The north jamb is entirely exposed to outdoors environment and its selenite blocks show severe weathering, mostly due to rain and biological colonisation. Each of them is incised with a 'branch' mark but the upper one can be barely seen (Fig.5.78). The effects of rain water are apparent on the gypsum slabs of the floor and the cists. The floor is paved with selenite slabs that are completely burnt and the majority of them are also stained black (Fig.5.79). The same applies to the lining of the cists (Fig.5.80). Hallager (1977) dates the floor of this magazine to the beginning of the LMIIIA renovation/restoration works in the palace, probably contemporary with the earlier floor that is visible in Magazine XII. Along the south and north walls there are remains of wall dadoes that run along the entire length of the corridor. A 'gate' mason's mark is also visible on the surface of a reused block of the south wall that is almost unaffected by fire (Fig.5.81). It was either the dadoes or wall plaster that dressed the wall at an earlier time that protected the lower part of the wall from fire. A second 'gate' mark and a 'double axe' are preserved on two blocks of the north wall.

Magazines XIV-XVIII

The last four magazines are all exposed to rain and the preservation of gypsum is very poor (Fig.5.82 and Appendix 1: Plan 5). However the same general observations can be made on the walls as regards the construction technique. Several selenite blocks and very few 'nodular and lenticular' are built in the walls in secondary use. The east entrance of Magazines XIV-XVI has been blocked and there are no gypsum jambs on this side. A course of wall dadoes was installed against this wall once their east entrance was blocked (Fig.5.83). These magazines have access from the west. There is a large selenite block at the west end of the south wall of Magazine XV (Fig.5.84) and another two, one on top of the other, at the west end of north wall of the same magazine (Fig.5.85). There is no gypsum floor pavement in these magazines apart from some traces found in Magazine XV. Magazine XVII, however, also has an entrance in the east with the usual large gypsum jambs. Both selenite blocks of the south jamb and the lower one of the north (Fig.5.86) are preserved but heavily weathered. The floor is also paved with gypsum slabs, mainly selenite that is heavily burnt and large missing parts of it are reconstructed in concrete. There are four floor cists but their gypsum lining is missing (Fig.5.87).

The Long Gallery of the Magazines

The Long Gallery of the West Magazines (Corridor 40) starts at the third magazine and runs through the end of the west magazines (Fig.5.88-89). From the fourth magazine to the south jamb of the fourteenth there are twenty-seven floor cists. They are grouped in two types of which the first 'type A' is lined with gypsum that is also sealed with lead sheet and corresponds to the first seven from the south, and the second, 'type B' is lined with limestone and sealed with plaster and corresponds to the remaining twenty cists that form four groups of five (Evans 1921: 453, Fig. 325). The cists of 'type B' are deeper and larger and probably served as vats for oil. They were closed and paved over at the end of the MM III Period. The pavement went through a series of restoration in the succeeding periods as well as in modern times during the restoration campaigns of both Evans and N. Platon (Fig.5.90). The north part of the corridor from Magazine XIV onwards is narrowed by the side wall that supports the staircase which starts here and continues to the north up to the end of the west magazines. It preserves the great majority of the original slabs that are all burnt and stained black (Fig.5.91). Along the east wall of the Long Gallery are built several selenite blocks with several mason's and tool marks, that are partly or entirely burnt and are clearly in secondary use. A wall pier opposite the south jamb of Magazine XI, made of selenite, very similar to the jambs of the magazines, is embedded in the wall. The upper block of the pier has three different mason's marks: a 'gate' and a 'star' that are overlapping and a 'double axe' that is lightly incised next to them (Fig.5.92) (Hood 1987).The visible mason's marks, four `double axe', four 'star' and four 'gate' marks including the overlapping ones in (Fig.5.92), are indicated in Fig.5.94. It is mostly interesting that some of the double axe marks which are so roughly cut on the surface of the stone that the outline of the chisel can been traced (Fig.5.93). The treads of the staircase at the end of the 'Palace Treasury' that was mentioned above are also made of selenite but only the four first steps are original while the upper two have been replaced by modern selenite with large crystals (about 5cm long). On the west side of the staircase there is a pier that is also made of selenite, with mostly vertical crystals. The pier and the original steps are all burnt and most of the pier is also stained black. This staircase is a representative example of the difference in the macroscopic characteristics between affected and unaffected by fire selenite (Fig.5.95-4.96).

Western Palace Section

At the south end of the east wall there are two doors that connect the West Magazines with the Central Court through the Western Palace Section that occupies the in-between area. The entire west wing of the palace was devoted to storage of oil and precious materials and to cult purposes until the end. According to Evans in the Old Palace Period the West Palace Section consisted of three isolated blocks or 'insulae' that were later, in the New Palace Period, incorporated in a unitary plan: the West Central Insula Middle that includes the Pillar Crypts, the Lobby of the Stone Seat, the Room of the Stone Vats, the Temple Repositories and the Room of the Tall Pithos, the West Central Insula North that was later occupied by the Throne Room system and the West Central Insula South that includes the Early Passage with Proto-Palatial Magazines the 'Room of the Chariot Tablets the Central Clay Area the Court of the Altar and the Pillared Portico'. Evans argued that the majority of the basement plan of this section was maintained with the exception of the area of the Throne Room that was completely remodelled in the New Palace Period (Evans 1921: 203, Fig. 152, 224-225, 424-425).

The West Palace Section had an early orthostatic façade facing the Central Court with large gypsum orthostates that are close parallels to those of the west and the south facades. In the new Palace Period the facade was moved about three meters further to the east. Parts of the early facade are the rounded orthostates at the north-east corner of the section (Fig.5.97), and those in front of the Temple Repositories (Room 34) (Fig.5.98) that continue up to the south end of the Stepped Portico (Area 24) (Fig.5.99-4.100) (Evans 1928:798-803, Fig. 525, Evans BSA X:26-28). A little further to the south, next to the clay bath are another two burnt selenite blocks (*KN*168-169) set on a course with east- west orientation that resemble the large orthostates of the façade and are probably associated with it. This section is in general one of the most complicated areas of the palace, subjected to various modifications as demonstrated by Hallager (1987) in his attempt to reconstruct the different phases. Based on Evans' and Hallager's work I have considered that the majority of the structural gypsum such as wall piers, jambs and pillars as early features most probably contemporary with the façades.

Early Passage Way with Proto-Palatial Magazines

The West Palace Section South is defined by the Corridor of the House Tablets on the north and the Early Passage Way with Proto-Palatial Magazines on the south (Appendix 1: Plan 3). Along the early passage are the wall piers of the Proto-Palatial Magazines that consist of two selenite blocks each and are very similar to the jambs of the West Magazines as regards their dimensions and the variety of gypsum that is used. A wall pier consisting of two blocks is also found at the entrance (*KN*1761-1762) with a front side at the Long Gallery of the West Magazines. The second pier (*KN*1759-1760) is at the corner of the room west of the Steatite Vase Room (Room 27) where broken gypsum blocks and slabs, probably collected from the this area, have been collected in a pile. The lower block of this pier (*KN*1760) is marked with a cross paté or croix pommée and carries flat chisel marks as well while the upper (*KN*1759) is probably in secondary use as suggested by its placement in direction different from that of the lower block (Fig.5.101a). The third pier forms the south and of the west wall of the Steatite Vase Room. The lower block (*KN*1758) is marked with two *cross paté* marks and the upper with a gate (Fig.5.101b). The fourth pier forms the south end of the east wall of the **Steatite Vase Room**. The lower block (*KN*1756) is marked with two overlapping signs a *cross pate*' and a 'double axe' while the upper (*KN*1755) is marked with a *cross* *paté* (Fig.5.101c). The last pier forms the end of the east wall of the Stone Vase Room (Room 26). Its lower block is missing and is reconstructed with concrete while the upper (*KN*1754) which is placed on top of the concrete is a selenite, unaffected by fire with a *cross paté* mark on the east side and its position does not seem to correspond to the original one (Fig.5.101d). The lower block of the third pier is also unaffected by fire whereas the rest are all burnt. Thus the fire marks here indicate the direction of the fire that obviously came from the West Magazines and spread as far as the third pier (Fig.5.101c).

In the **Stone Vase Room** are abandoned two broken selenite blocks (*KN*1769-1770) and the remains of a gypsum floor pavement made of nodular and lenticular gypsum, of which only the north part is preserved (*KN*1764-1768) (Fig.5.102). The pavement is all burnt and stained black. It is made of nodular and lenticular gypsum and probably belongs to the New Palace Period or even later to LM II-III.

On the south wall of the Early Passage with Proto-Palatial Magazines there are seven reused selenite blocks set on a rough course, of which only the upper part shows fire marks that again, extend as far as the third pier. Four of these blocks are incised with deep *cross paté* mason's marks and carry several marks of tools (Fig. 104a-d). Evans noted that these are the only *in situ* blocks that have this sign, whereas it occurs on several reused gypsum blocks in Magazines C, I, II, on the east wall of the Corridor of the Stone Jambs and of the Long Gallery of the West Magazines. He emphasises that the sign occurs ten times in this area nine of which are on gypsum (Evans 1928:663-664, Fig. 424). As shown in the above description of the magazines the cross *paté* mark is also lightly incised on the south jambs of the first and the second magazines that are in situ and already marked with a deeply cut gate'. Furthermore, it occurs in the wall piers (or jambs) of the **Corridor of the House Tablets** (Corridor 28) which are very similar to the aforementioned ones and consist of two blocks of selenite that are all burnt (Fig.5.103). There are four of them (*KN*1925-1926, *KN*1929-1930, *KN*1931-1932, *KN*1933 and opposite it 1933a) two blocks of which are marked with *cross paté* (*KN*1926 and *KN*1932') one with a star (*KN*1933) and another one with a double axe' (*KN*1933a). A third cross *paté*' is found in this area on a reused selenite block, built into the south wall of the south magazine which also contains tow selenite floor slabs. The Corridor of the House Tablets is also paved with gypsum slabs, mostly selenite burnt and stained.

East of the Room of the Stone Vases, is the **Room of the Chariot Tablets** (Room 25) that is even more complicated as regards its chronological phases (Fig. 5.105). The date of the gypsum remains here is uncertain and some of them may be in secondary use (Hallager 1987). From the east wall open two doorways with L-shaped gypsum doorjamb bases (*KN*1739-1738 restored in concrete and *KN*1749-1750). The north leads to a small chamber and the south leads to a restored staircase of which Evans found part of gypsum steps and the upper and lower staircase blocks (Evans 1928:801-802). The north-west corner of the room is formed by a large selenite jamb with well oriented vertical crystals (*KN*1751), whilst in the middle of the room there a square pillar base (*KN*1743) of the same material and few irregular slab fragments on the floor which do not seem to be part of the original floor. All the jambs and the prier base are made of selenite that is now burnt to white. North of it there is a space probably a corridor (see Hallager 1987) that is paved with modern gypsum slabs (*KN*1771-1775) presumably replacing the remains of original ones found there and two steps (*KN*1777-1779) with original gypsum fragments that lead to the Lobby of the Stone Seat.

West Palace Section Middle (29-34)

The West Palace Section Middle (Rooms 29-32) with the **Pillar Crypts (29 and 30)** and the **Temple Repositories (34)** has a strongly ritual character and contains gypsum elements of both Old and New Palace Periods (Appendix 1: Plan 3). The pillars of both West and East Pillar Crypts are made of selenite blocks with deeply incised double axe marks. Evans considered them as foci for offerings as well as support for the upper floor that was also devoted to the Central Palace Cult (Evans 1921:218). Each pillar consists of four blocks of selenite that are all burnt and stained black. In the West Pillar Crypt (29) all four sides of the blocks (*KN*1981-1984) have a double axe mark while the upper one has a fifth on the top surface (Evans 1921:425). The floor is paved with a central panel of gypsum slabs enclosed by an outer frame of limestone (Fig.5.107). In the East Pillar Crypt (30) only three sides of the pillar blocks (*KN*1985-1988) are incised (Fig.106). The floors are paved with gypsum apart from the two vats that are dressed with limestone and are probably related to liquid libations. The doorjamb bases of all doors are also made of selenite. It is not possible to identify the variety of gypsum that is used for the floor slabs, as most of them are not well preserved and are covered with dust and surface encrustations. However most of them seem to be made of selenite that has been affected by fire. Evans dates the pillars to the early days of the palace but the floors may have been repaved in some later period.

To the north of the Pillar Crypts and west of the **Vat Room' (31)** is the **Room of the Niche'** and its adjacent magazines, with early features such as the three wall piers (*KN*1753-1758) each consisting of two selenite blocks with deeply incised mason's marks (Fig.5.108) (Appendix 1: Plan 3).

The Vat Room itself is also one of the earliest features of the palace. Part of the Vat

Room' and the magazine that is immediately north of the East Pillar Crypt, are paved with gypsum slabs that cannot be closely examined. East of these magazines are another three rooms, the **Temple Repositories (34)**, the **Room of the Tall Pithos (33)** and the **Lobby of the Stone Seat (32)** that have been subjected to several modifications and contain gypsum elements from various periods. The cists that are visible in the temple repositories represent two different phases. The large ones are MMIII and are lined with limestone slabs (the west one) and masonry (the east one) while the small superficial cist in the middle is Late Minoan and is lined with gypsum slabs (*KN*1768-1772) (Evans 1921:463-468). In the Room of the Tall Pithos there are irregular gypsum floor slabs of both selenite and nodular and lenticular gypsum that do not seem to be in their original placement.

The **Lobby of the Stone Seat (32)** named after the gypsum bench that is built against the north wall of the room, has a typical Minoan floor pavement with a central compartment made of irregular slabs of iron stone outlined by red painted plaster (hard grey limestone) and an outer frame of gypsum slabs around it (*KN*1880-1899) (Fig.5.109 and Appendix 1: Plan 3-4). Most of the original floor slabs have been replaced with modern ones by N. Platon. The original ones in front of the bench are made of nodular and lenticular gypsum that is burnt and stained (*KN*1894-1897). Similar floor pavements with a combination of iron stone or schist are found at Agia Triada and Megaron Nirou. The bench is also a very close parallel to those of Agia Triada, Phaistos, Megaron Nirou and Pyrgos with alternating *metopes* and flat pilasters (Fig.5.110). The base and the seat of the bench are made of selenite that is also affected by fire and are cracked and stained black (*KN*1828-1834) (Appendix 1: Drawing 18). The back of the bench is also dressed with selenite slabs divided by timber (*KN*1826-

1827). A unique feature in this room is that the north wall is built mostly of stacks of broken gypsum slabs that are in secondary use and are visible at the back of the bench (Fig.5.111). This is the only case where gypsum slabs have been seen in secondary use built into the walls, and are possibly fragments of wall dadoes rather than paving slabs which would normally be paved over as revealed in various stratigraphic sections in the Palace (in the Queen's Megaron, West Magazines, etc.).

The staircase that leads from here to the Central Court is made of limestone, although the half of the first two steps consists of burnt selenite (*KN*1815-1816) and the half of the third is replaced with modern gypsum (*KN*1817). Evans (1900:28) states that only the two lower steps were preserved and assumed that the upper two were made of wood, which means that the only original stone here is the burnt selenite (Fig.5.112). The staircase is flanked to the south by one of the selenite orthostates of the early façade that was mentioned above and to the north by a bench that is also dressed with gypsum. In front of the room is one of the lower blocks (*KN*1818) of selenite pillars that formed the Pillared Portico on the Central Court, which Evans partly restored (Evans 1928:802-803) (Fig.5.113 and Appendix 1: Plan 4). A second pillar block is further to the north on the same line (*KN*1825).

In between these two pillars Evan's recognised the remains of a small **Tripartite Columnar Shrine** facing the Central Court that gave an answer to the somewhat strange arrangement of the architectural gypsum in this area (Evans 1928:805, Fig.526). Another two similar blocks of selenite, set on the same line, are standing on either side of the *polythyron* of the Anteroom to the Room of the Throne which seem to belong to the same series of pillars that run along the entire length of the facade (Fig.5.114).

The north part of the West Palace Section is occupied by the **Throne Room Complex**

(41-48), the **Magazine of the Jewel Fresco (39)** and a second one parallel to it and the **MM III Magazine with Cists (38)** (Appendix 1: Plan 3 and Drawing 21). In the latter, magazine (38), there are the remains of three cists that are similar to those of the Temple Repositories' and date to the MM III period. They were later filled in, in LM I, and paved over with gypsum slabs forming a corridor of which the walls were also dressed with gypsum dadoes. In a succeeding period the corridor was cut by the south wall of the Anteroom to the Room of the Throne and was again filled to support the threshold of the Stepped Porch that was built above (Evans 1903:31-32, Fig.9-10, 1921:454-455, 1928:810-811, Fig 529). Only one gypsum floor slab (*KN*2185) and four dadoes (*KN*2181-2184) have been maintained in situ' above the earlier cists and are all made of nodular and lenticular' gypsum cut parallel to the laminations (Fig.5.115).

In the **Magazine of the Jewel Fresco (38)** there are no visible traces of gypsum apart from reused blocks of selenite built into the walls that are similar in construction to those of the West Magazines. The same construction is observed in the next magazine to the north where three deeply incised gate masons marks were recorded. The latter also contains a rather strange structure, made of nodular and lenticular gypsum slabs (*KN*2177-2180, Appendix 1: Drawing 21), that could be a partly preserved cist and remains of gypsum floor slabs (Fig.5.116). A door on the north wall of this magazine leads to the Room of the Throne (42) through a small corridor.

Throne Room Complex (41-48)

As already mentioned the Throne Room Complex was built in the last period of the Palace and cut through the earlier orthostatic façade of the Palace (Fig.5.117). Evans believed that this area was remodelled completely at the beginning of LM II and represents a single phase (Evans 1900: 35-42, 1928:802-803, 812-814, 1934: 901-

919). Mirie (1979 cited in Niemeier 1987) demonstrated that the history of these rooms goes back to the Old Palace and identifies four building phases. He dates the main structure and the floor to MMII and identifies the installation of the benches and the throne seat as the next phase. The architectural gypsum of this area is the best preserved in the Palace as it was roofed over shortly after its discovery. Judging from the character of the architectural gypsum in this area I believe that the majority of it was installed as part of the same renovation-refurbishing campaign that took place in the beginning of the LMI period and included the Domestic Quarters and the North Lustral Basin.

The **Anteroom to the Room of the Throne Seat (41)** has an entrance from the north and a four-door *polythyron* facing the Central Court. The L- and T-shaped doorjamb bases of the *polythyron* are all original and are made of selenite that is now burnt to white (*KN*2003-2007) (marked blue in Fig.116). The treads of the stepped thresholds of the *polythyron* (*KN*2029-2035) are also original and made of selenite that is burnt as well, whereas the treads of the next two steps are all replaced with modern gypsum that is mostly chaotic selenite (marked orange in Fig. 5.118). However, in front of the north entrance, where all four steps are original, the two lower ones (*KN*2011-2014, 2028) are made of nodular and lenticular gypsum (marked with red in Fig. 5.118), while the upper ones (*KN*2009-2011) are made of selenite (Fig.5.119).

According to Mirie (1979 cited in Niemeier 1987) the steps were added in two different phases after the installation of the benches and the seat, due to the rise in the level of the Central Court and this may explain the use of different variety for the upper steps. However the use of selenite for the exposed or semi-exposed parts of the building is a common practice which also gives a good explanation for its exclusive use in the upper steps towards the court and thus I would not use it a criterion for dating the upper steps later. The lower steps that were made of nodular and lenticular gypsum seem to have been quarried and installed at the same time as the rest of the fittings in the two rooms and the lustral basin. This is the first area to be discussed that presents a significant amount of nodular and lenticular gypsum that seems to be a late feature introduced in the New Palace Period. As will be seen, the majority of the ornamental gypsum that is used in this area as well as in the Domestic Quarter and the North Lustral Basin is nodular and lenticular.

In the anteroom there is a typical Minoan floor pavement with a central square of hard irregular limestone framed by rectangular slabs of gypsum. Similar floors are found in the Room of the Throne, the Lobby of the Stone Seat, Rooms 5 and 12 in Megaron Nirou and Room 12 in Agia Triada (Fig.5.120). Almost half of the gypsum floor slabs here (*KN*2038-2039, 2043, 2045, 2050-2056) have been replaced with modern slabs byN. Platon (marked orange in Figure 5.118). The rest of them, the original ones, consist of selenite that is burnt, apart from one at the south-west corner (*KN*2040) that is made of nodular and lenticular gypsum (marked red in Fig. 5.118).

I believe that originally only one variety was used for the floor and that the introduction of a second one was the result of renovation in the succeeding and in modern periods. It seems quite reasonable to replace floor slabs that are worn and if the original variety has been the nodular and lenticular one that is more difficult to obtain it is not surprising to find substitutes made of selenite that fill in only the spaces of the worn slabs without repaving the entire floor. Along the south wall there is a bench with pilasters that covers its entire length (Fig.5.121). Another two benches built against the north wall have a gap in the middle where a wooden replica of the throne seat has been placed (Fig.5.122, and Appendix 2: Drawing 18). The top of the benches is made of nodular and lenticular' gypsum but in the construction of the base both varieties have been used. The nodular and lenticular gypsum is also cut in both directions vertical and parallel to the veins. Therefore I cannot suggest with certainty that there is a consistency in the use of a decorative pattern that the gypsum surface can provide when cut deliberately in a certain direction. However there is a tendency to display surfaces that are cut parallel to the laminations of the nodular and lenticular gypsum and show interesting wavy veining.

The **Room of the Throne (42)** has a similar arrangement with benches along the south, north and west walls and the typical Minoan floor with a central square compartment of hard limestone and a gypsum frame around it (Fig.5.123-124 and Appendix 1:Drawing 19). The doorjamb bases of the double door that connect it with the anteroom are made of nodular and lenticular gypsum, whereas the thresholds are made of selenite that is now burnt and difficult to identify. The floor slabs are all original and are all made of nodular and lenticular gypsum, apart from one in front of the south bench (*KN*2097) that is made of selenite. The same variety is used for the top of the benches and the back of the south bench while their base may have some selenite but is not always possible to be certain of the variety, as most of them are stained and encrusted. This is a problem that I was often confronted with in the restored areas of the palace; where there are no fresh surfaces washed off by rain to facilitate the secure identification and description of the stone varieties. The throne seat itself is also carved out of a single block of nodular and lenticular gypsum that is also stained and encrusted (Fig.5.124).

The staircase that leads to the **Lustral Basin of the Room of the Throne (43)** has treads of selenite apart from the last two (*KN*2151-2152, 1 and 2 in Hood's plan) that are made of nodular and lenticular gypsum. The balustrade of the staircase is also dressed with nodular and lenticular gypsum while the pier is made of vertical selenite (Fig.5.126). The walls of the lustral basin are dressed with selenite cut in a direction parallel to the veining, while the floor slabs consist of selenite cut in a direction parallel to the crystal growth (Fig.5.127 and Appendix 2: Drawing 20). The selenite floor slabs here are unaffected by fire while the wall dadoes seem to be affected, although it is again very difficult to discriminate in between affected and unaffected material when the variety is fine grained and especially in cases with staining and encrustation. The unaffected selenite floor slabs are most likely modern, as suggested by the state of preservation, but there is no record of such an intervention. Although the walls have been plastered and painted either red or with a reproduction of the griffin wall paintings above the west and the south bench, a reused gypsum block that is built into the south wall of the lustral basin was carefully plastered around so that its surface, incised with a deeply cut gate mark, can still be seen (Fig.5.126).

The rooms behind the Room of the Throne (**Rooms 44-48**) do not present any significant features as regards the usage of the stone apart from the gypsum seat and bench fragments found in the **Room of the Lady's Seat (48)** and the some wall piers and reused blocks with gate marks that are reminiscent of what we have seen in the majority of the walls in West Wing of the building. The floors of these rooms are now also covered with gravel and since there is no indication of stone paving in Hood's plan I assume that there is not more gypsum in this area.

The corridor and staircase on the north of the ante-room that lead to the floor above the Throne Room Complex contained both varieties of gypsum. The first slabs at the entrance of the corridor are made of selenite while the next ones towards the staircase as well as the treads of the first flight of the staircase are made of nodular and lenticular gypsum that is, however, fragmentary. The intention to protect the fined grained variety of gypsum by placing gypsum with coarser crystals at doors or the staircases that opened to outdoors areas is once more documented here. The second flight of the staircase in mostly restored in concrete with a few gypsum fragments of both varieties embedded in them.

In between the Tripartite Columnar Shrine, and the Anteroom to the Room of the Throne is the **Stepped Porch (37)** and the **Central Staircase** that gave access to the Piano Nobile that is restored above the West Palace Section (Fig.5.128) (Appendix 1: Plan 4). They were constructed at the beginning of the LM I period before the remodelling of the Throne Room Complex. There are only four original steps of the porch preserved that are made of hard limestone and two gypsum column bases (*KN*2001-2002). The first is embedded in the middle of the second to fourth steps and is made of selenite that is mostly affected by fire apart from a small area close to the base. The second column, also made of selenite, is embedded in the middle of the last steps of the first flight that are entirely restored with concrete. It is only partly preserved and was found in the basement area below its present position (Evans 1928:812, 819, Fig. 536). The pier that supported the column base of the balustrade of the first flight of the **Central Staircase** is one of the few structural elements that are made of nodular and lenticular' gypsum instead of selenite that is the usual variety that we have seen up to now in such features. The laminations of the stone are horizontal and it is completely burnt (Fig.5.129). The north side of the block that was found in this position, slightly sunken, showed the marks and ledges of four steps which were reconstructed by Evans. Gypsum fragments that were found in this area indicate that the staircase was also made of gypsum (Evans 1928:816-818, Fig. 534, 535). Today there are only two fragments of selenite embedded in the concrete steps of the staircase, these are unaffected by fire, quite well preserved and are most probably modern.

The gypsum column and doorjamb bases that have been placed by Evans in the restored upper storey of this area known as Piano Nobile were not recorded and registered in the catalogue but will be briefly described. They were found in the debris of the lower floor and were placed by Evans in an arrangement that he thought would be reasonable according to the structural support provided by the lower floor. They are made of selenite that is mostly burnt except for one column and one doorjamb base that are made of nodular and lenticular gypsum.

It is not possible to make any further observations as regards the use of gypsum in this area, but I assume that gypsum was used mainly for column bases, piers, jambs and perhaps floor and wall lining. However, Evans does not mention any significant quantities of slabs fallen from the upper floors, as would be expected if it had been extensively employed for dressing walls and floors.

Before I move to the east wing, where the majority of the architectural gypsum is concentrated in the Domestic Quarters and the rooms that occupied the area of the South East Insula', I will discuss the architectural gypsum of the area north of the West Palace Section' that includes the **Initiatory Area (62-63)** including the **North Lustral Basin**, the **North Portico**, the **North-West Magazines** and **Rooms 51-54** that occupied the area of the Early Keep (Appendix 1: Plan 3, 5).

North-West Section

Initiatory Area

The far north-west corner of the **Initiatory Area (63)** is outlined by a course of large selenite rocks that is most likely part of an orthostatic façade similar to the south and west ones that were described above. The orthostates are heavily weathered, totally burnt and partly stained (Fig.5.130). The south wall of this area, including its extension in the **Anteroom of the Initiatory Area (62)**, is amongst the most problematic as regards its chronological phases. The gypsum blocks that are built into the east part of the wall (Fig.131) cannot be dated to a certain chronological phase of the building as they are obviously re-used from an earlier structure as noted by Evans as well (Evans 1900:45). However, at least one course of large selenite ashlar blocks must have existed along this wall.

Hood has pointed out to me that the unaffected blocks of selenite (*KN*1322-1325) (Fig.5.132) that form the lower course of the west part of this wall are "part of the earliest Early Palace walls along with the wall that Colin Macdonald uncovered in his excavation in 1987" (Hood, personal communication on 11/10/1996), which was described with the area of the Early Magazines (between Rooms 17 and 18). The ashlar of this area seems to be Proto-Palatial, but not necessarily within the same chronological phase. The selenite blocks that Hood places in the earliest phase, for example, are all unaffected by fire and are found on a lower level than those in the Anteroom of the Initiatory Area (*KN*1208-1212) that are approximately of the same size but are all burnt and which might be contemporary but reused in a later phase.

According to Evans the Initiatory Area with the ante-room and the North Portico were originally built in MM II and were slightly modified in the beginning of the MM III when the Bastion of the North Entrance Passage superimposed the east wall of the portico, and when the North Lustral Basin was remodelled (Evans 1921:216-217, 405-410). Whatever the case, the gypsum remains in this area are mainly ashlar blocks and doorjamb bases that are all made of selenite. During the remodelling of the building the ashlar may have been moved and reused, but the doorjambs are left in their position, indicating in many cases earlier doorways that have been blocked.

The **North Lustral Basin** is the most elaborate example of this architectural scheme and a close parallel to that in the Room of the Throne (Fig.5.133). The entire structure is dressed with gypsum including the steps and descending balustrade of the staircase, the pillars, column bases, thresholds, doorjamb bases, walls and floor (Appendix 1: Plan 5 and Appendix 2: Drawing 22-25).

A quite significant observation here is the use of selenite for the first flight of the staircase (*KN*1232-1239) and the staircase pier (Fig.5.134) while the only column base that is preserved (*KN*1265) is made of nodular and lenticular gypsum as the rest of the fittings. In clear contexts that all gypsum fittings date to the same period there has been observed that there is a tendency to use coarser gypsum varieties for the more bulky structural architectural members and for those that are exposed to rain.

The dadoes show the characteristic surface of slabs that could have been easily sliced along the laminations and which can be seen naturally split in the outcrops of Foinikia along the sides of the main road that cuts through them (Fig.5.135).

The long doorjamb bases of the double door in front of the entrance (*KN*1217-1219) (Fig.5.136) and a coping slab of the south wall (*KN*1309) (Fig.5.137), provide the evidence that proves that the fine grained veined gypsum that is found in the interiors of the palace, mainly in the Neo-Palatial structures, is primary nodular and lenticular, gypsum that has been affected by fire. The macroscopic result of this alteration can be confused easily with the laminated variety of gypsum known as balatino that is largely used at Phaistos and Agia Triada. However, in these cases we can clearly observe the pseudomorphs of the crystals in nodules and the lenses of the material (Fig.5.138). The coping slab (*KN*1309) is only partly affected by fire and demonstrates clearly the transition and the macroscopic differences between affected and unaffected parts of this variety (Fig.5.139).

It seems hard to believe that this is the only case where this variety occurs only partly affected by fire, but as already mentioned, it is mostly restricted to the interior spaces and is usually covered with environmental depositions or encrustations that do not allow close observation of the crystallographic characteristics. It is therefore possible that such examples exist throughout the palace but are not visible to the naked eye. After closer examination of the south doorjamb, unaffected crystals of the core material were observed as revealed after dissolution of the superficial burnt layer. The same observation is made on the burnt selenite treads of the first flight of the staircase, where the superficial layer of affected selenite has been dissolved away, revealing the unaffected core with translucent crystals (Fig.5.140).

North West Magazines

The **North West Magazines** immediately south of the North Lustral Basin are constructed in a way similar to that of the West magazines (Fig.5.141). There are again several burnt and partly burnt blocks of selenite in secondary use, built into the walls and the western-most preserves on its south edge the lower block of a large jamb

(*KN*1372) with projections that held the door posts, similar to those described in the section of the magazines (Fig.5.142). The **Corridor of the Stone Basin (49)** between the North West Magazines and the Throne Room Complex, with a north-south and an east-west axis is paved with gypsum slabs that are not well preserved and do not follow a regular arrangement of rectangular slabs (Appendix 1: Plan 3). These were probably found in the corridor but not in their original position. They have not been measured as individual fragments but their approximate volume has been included in the calculation of the total volume of gypsum. Along the north-south axis of the corridor are the usual reused selenite blocks built into the west and east walls, the most remarkable being an unaffected block (*KN*1374) (with a large and deeply incised branch mark) (Fig.5.143).

The last significant remains of gypsum in the north-west section of the palace are found in the **Room of the Lotus Lamp (51)** that overlaid part of the Early Keep or Original MM I Insula (Fig.5.144). The floor pavement of this room is only partly preserved and has suffered severe dissolution. All the paving slabs and a displaced L-shaped doorjamb are nodular and lenticular gypsum. Reused blocks of selenite are as usually found in the walls of this room and the adjoining ones (Room 50 and 52).

North Section

On the north the most interesting features are the large (85x85cm) square pillar blocks of selenite at the **North Pillar Hall** (Evans 1921:398-401, Fig. 287). Four of them (*KN*1186-1189) that are preserved to a considerable height are made of selenite while another four are reconstructed with concrete (Fig.5.145, Appendix 1: Plan 6). One of them (*KN*1187) is unaffected by fire, and when compared to the burnt blocks that are next to it, demonstrates once more that selenite, has a much higher resistance to weathering when it has not been subjected to dehydration – re-hydration cycles (Fig.5.146).

North-East Section

Moving towards the east wing of the palace from the north there is not much gypsum preserved in original context. The main layout of this part of the building dates to the MM III/LM I period but there is a continuity of MM II structures that have been incorporated. However this area has been subjected to various modifications in the LM III period and therefore lots of the gypsum blocks of the original structure have been displaced and reused (Evans 1930:255-268).

The most significant gypsum elements in this area have been recorded and therefore the basic information such as location, size, variety, function and possible date can be obtained from the catalogue (Appendix 1: Plan 7-8). Few blocks and doorjamb bases are found along the wall of the **Norh Entrance Passage (59)**, the **North East Magazines** in the **Area of the Grooved Partitions (71)**, the **North-East Portico** the **North-East Veranda (74)** and the **Court of the Stone Spout**. The most interesting features are the grooved partitions in the area named after them (Fig.5.147) and the triangular blocks (*KN*1125-1127, 1129) of the north wall of the North East Veranda (74) that are set in two courses (Fig.5.149). They are made of selenite with an average crystal size of 3cm and are unaffected by fire. The triangular blocks probably belong to the original MM III structure (Evans 1930:263-268) or to an even earlier one. The **Room of the Gypsum Dado** immediately west of the North-East Hall, was all paved and veneered with nodular and lenticular gypsum of which very few fragments are preserved (*KN*1097-1104) (Fig.5.147, Appendix 1: Plan 6, Appendix 2: Drawing 13).

Domestic or Residential Quarter and Royal Magazines

The main section of the East Wing that contains gypsum in a good context is the Domestic or Residential Quarter and the adjoining Royal Magazines that are divided in two parts, the Corridor of the Bays (76) and the Magazine of the Medallion Pithoi (77) (Appendix 1: Plan 4, 6).

Royal Magazines

The layout of the Royal Magazines indicates that the structure supported an upper East Hall built before the end of the MM III period and renovated on the same layout in LM I. The magazines however do not have access to the upper hall. They are connected with the first floor of the Domestic Quarter and were probably designed to serve the needs of storage for this architectural unit. The Magazine of the Medallion Pithoi is paved with gypsum slabs that are burnt and stained black (Fig.5.150). They are mostly made of selenite and despite the dramatic alteration of its macroscopic characteristics the pseudomorphs of the original crystals are still visible (Fig.5.151). The MM II floor that is exposed under the MM III gypsum floor pavement in a section in the middle of the room is paved with limestone which may indicate that gypsum slabs were not used to such an extent in the interior of the earlier phases of the palace but again this cannot be proved by the observation or the few scattered stratigraphic tests that are visible at the present (Evans 1921:320-323, Fig.233-236).

The Corridor of the Bays is also paved with selenite slabs which, are partly preserved and are burnt, but not stained like those of the previous magazine which implies a different function for the two magazines. It is almost certain that oil was kept in some if not all of the Medallion Pithoi. As has been seen throughout the palace, black staining occurs either in closed spaces where the smoke was trapped or at the storage areas. Especially on some of the floor slabs in the magazines, the form of the black staining strongly resembles liquid stains.

Domestic Quarter

The great majority of the Domestic Quarter and especially its interior belong to the transition from the mature MM III period to the beginning of LM I and can be seen as the major project for the masons and quarrymen of Knossos in the New Palace Period. However, the cutting of the bedrock to the east of the central court against which is built this section, as well as the drainage system, go back to the MM II period. Some basic walls of the earlier structure were incorporated in to the new construction but others were demolished and the entire structure was redesigned (Evans 1921:325-327). This section of the palace is the most representative example of the elite Neopalatial architectural style where gypsum becomes the chief decorative stone. In this new era of the palace there is very little gypsum used in construction. It is not used for ashlar but only for some wall/staircase piers and doorjamb bases.

As already demonstrated in the description of the west part of the building, most of the major structural gypsum that can be seen around the palace has survived from the Old Palace Period and is in secondary use. In the Domestic Quarter there are wall pier, pillar and staircase blocks always made of selenite which could also have survived from the earlier phase of the palace. The only gypsum ashlar that is found in this section is the lower course of the north and south walls of the light well in the Queen's Megaron which Evans dates to the MM II period (Evans 1921:328). It should be noted that these blocks show early characteristics such as the stone variety that is vertical selenite partly burnt and the mason's marks (double axe and branch) that are incised on some of them.

The major rebuilding and refurbishing work at the Domestic Quarter required about 512 square meters of gypsum, mainly in slabs, for the facing of the floors and the walls that had to be cut precisely to be adjusted to the walls. The dado slabs were almost two meters high and their production must have required extensive research for suitable outcrops and skilful quarrymen and masons.

The Domestic Quarter represents a clear example of a designed interior decoration scheme, which makes use of the different patterns that gypsum varieties, can provide when cut in different directions. The gypsum varieties of the ground floor are colour marked in (Fig.5.152). This figure gives a good idea of the extent of gypsum decorations in this section of the building. The same layout was repeated on the first floor where only doorjamb bases, piers and part of the bench in Room of the Stone Bench are preserved. The gypsum of the first floor was recorded and registered on the plan by Doll published in Evans (1921:329, Fig. 240) while that of the ground floor was registered on Hood's plan (Appendix 1: Plan 7 and 7a).

The most outstanding architectural feature of this section is the **Grand Staircase (88)** with at least four and most probably a fifth flight (Fig.5.153). The landing and the treads of the first flight of the staircase (Fig.5.154), as well as the reads of the turn to the second flight (Fig.5.155), are made of nodular and lenticular gypsum with reddish-orange laminations (marked in red in Fig. 4.152) while the next flights (Fig.5.156) the pier blocks (Fig.5.157) and the coping of the balustrades (Fig.5.158) are made of selenite (marked in blue in Fig. 4.152), possibly indicating a more careful and elaborate decoration of the ground floor level that include public rooms such as the large hall of Double Axes.

The floor of the **Hall of the Colonnades (89)** (Fig.5.159) is paved with selenite except for the section on the north that forms a walk way towards the lower **East-West Corridor** that is paved with slabs of nodular and lenticular gypsum, cut in a direction vertical to the lamination layers, thus displaying a somehow parallel veining (Fig.5.160) (marked green in Fig. 4.152). The outer part of the floor towards the light well, as well as the column bases that are set on them, are made of limestone. The south, east and west walls of the hall are veneered with dadoes of nodular and lenticular gypsum that are cut in a direction parallel to the laminations. The dadoes of the south wall (*KN*615-616) are complete and reach a height of two meters above the floor level which is the height up to which most dadoes have been reconstructed (Fig.5.161). The dadoes of the north wall continue along the East- West Corridor (Corridor 87), of which the floor is made of selenite (Appendix 1: Drawing 9).

The **Hall of the Double Axes (90)** is paved with gypsum slabs and veneered with gypsum dadoes (Fig.5.162). The dadoes are poorly preserved on the north and south walls of the inner hall (Fig.5.163) (Appendix 1: Drawing 9-10). The floor slabs are also heavily weathered (Fig.5.164) and it is not always possible to identify the variety, although most of them show the characteristics of burnt selenite and have been marked as such in (Fig.5.152). It is quite interesting that in contrast to the rest of the floor, the thresholds of the *polythyra* are made of nodular and lenticular gypsum thus providing a contrasting decorative scheme. It is not possible to identify with certainty the variety of the doorjamb bases but most of them seem to be selenite as well as the pier block of the south east corner of the hall. The pavement of the L-shaped **Portico of the Hall of Double Axes (91)** (Fig.5.165) and lower pillar block at its south-east corner (Fig.5.166) are also made of selenite that is only partly affected by fire. On the west wall of the portico, immediately east of the Private Staircase there is a selenite wall pier at the corner and two wall dadoes next to it (Appendix 1: Drawing 13). The block is unaffected by fire, in an excellent state of preservation and incised with the double axe mark. The dadoes are made of nodular and lenticular gypsum and only their lower part is preserved up to a maximum height of 3.6 m (Fig.5.167).

A door on the south wall of the inner part of the Hall of Double Axes gives access to the **Dog's Leg Corridor (103)** that leads to the **Queen's Megaron** (Appendix 1: Drawing 10). The corridor is paved and veneered with selenite slabs apart from the last floor slabs (*KN*779-781) towards the megaron that are made of nodular and lenticular gypsum cut vertically to the laminations (marked green in Fig. 4.152). The next slab (*KN*782) that paved the threshold of the doorway that enters the Queen's Megaron' is also made of nodular and lenticular gypsum that is cut in a direction parallel to the laminations thus providing a surface with wavy laminations, just like those of the dadoes of the halls (Fig.5.168). The same variety is used for the floor slabs and dadoes of the Queens Megaron (103) and the **Bathroom (102)**, while selenite is used at the coping of the balustrades that divided the bathroom from the megaron (Fig.5.169-5.171). The wall dadoes of the bathroom are the best preserved ones throughout that palace and are all complete (Fig.5.167 and Appendix 1: Drawing 11) (restored view in Evans 1928:384, Fig. 384). The **Light Well of the Queens Megaron** is also paved with nodular and lenticular gypsum slabs but only three of them are preserved (*KN*943-945). Under the MM III-LM I floor of the Queen's Megaron and the Light Well there is an MM II mosaico floor pavement made of dark limestone (Evans 1930:366-367). A large part is exposed at the north-west corner of the megaron (Fig.5.172) and most of floor of the light well (Fig.5.173). The base of the pillared stylobates of the south and the east walls of the megaron are also built with selenite blocks which have light 'branch' marks and are earlier than the gypsum pavement and later than the limestone pavement (Fig.5.174) (Evans 1930:368). The first course of the north and south walls of the Light Well is made of selenite ashlar blocks that are unaffected by fire and at an excellent state of preservation while the rest of the wall continues above with limestone ashlar masonry (Fig.5.175-5.176) (Appendix 1: Drawing 12). On the outside of the south-east corner of the light well there is an interesting corner block of selenite that is set on a *krepidoma* surviving from an earlier structure that demonstrates the difference in the state preservation between affected and unaffected by fire selenite blocks (Fig.5.177). The east face of the block tha is unaffected by fire is perfectly preserved while the south is partially burnt and broken or was an originally rough side that would be covered by another block set next to it. It probably belongs to the same ashlar course as the block that is found at the other end of the wall in the L-shaped Portico of the Hall of the Double Axes, also set on a *krepidoma* (Fig.5.167).

The Private Staircase (104) that leads from the Queens Megaron to the first floor above is also made of selenite and is only partly preserved. The Corridor of the Painted Pithos (100) that connects the Queen's Megaron with the Room of the Plaster Couch or Toilet Room and the Court of the Distaffs is also paved and veneered with selenite but only few remains of the dadoes are preserved. Selenite is also used for the wall dadoes of the west and south walls of the Room of the Plaster Couch or Toilet Room (98) (Fig.5.178) and the fittings of the structure that is interpreted as a Lavatory or Latrine (Fig.5.179 and Appendix 1: Drawings 11-12). On the north-east corner of this room there is a corridor, towards the Treasury and the Hall of Colonnades, of which very few fragments of gypsum paving are preserved. The Service Staircase (Staircase 95) that leads from this corridor to the first floor must have been made of wood and only the stone casing is preserved (Evans 1921:335).

The remains of the first floor of the Domestic Quarter (Fig.5.180-5.181), which are mainly the doorjamb bases and the bench in Room of the Stone Bench' (Fig.5.182), are all made of nodular and lenticular gypsum that can be easily identified due to its exposure to rain that washes off any environmental depositions (Appendix 1: Plan 6a) . As already mentioned, it is very difficult and often impossible to identify the variety that is used for the doorjamb bases of the ground floor, as they are all built over and the few visible surfaces do not show any clean surfaces. The floor of the upper east west corridor is also covered by a wooden walk way and it is not possible to see the gypsum pavement, but the staircase at its east end that leads to the Lobby of the Wooden Posts is made of selenite although very little of it is preserved (Fig.5.183). There are also fragments which indicate that the floor of the Lobby of the Wooden Posts was also paved with selenite.

South East Insula

South of the Domestic Quarter' is the last group of rooms (Rooms 105-115) that occupies the South East Insula (Fig.5.184, Appendix 1: Plan 9-10 and Appendix 2: Drawing 8). This is a system of rooms that belong to the MM III period. The *insula* itself is divided into a north and south part. The southern part, with a small lustral basin (Room 113) (Fig.5.185), has a ritual character and may have served as a small initiatory area related to the south entrance of the building. The northern section that has a more residential character may have served as accommodation of a priest and includes a **Domestic Shrine of MM III date (105-107)**, the small corridor known as the

Magazine of the Lily Vases (107), a small chamber that is known as the **Magazine of the False-Spouted Jars (106)** (Fig.5.186) named after their contents and the **Bathroom by the Magazine of the Lily Vases (108)** (Fig.5.187) that functioned as a bath (Evans 1921:573-584). The gypsum fittings of this area are not well preserved and are mostly reconstructed in concrete while others have been replaced with modern gypsum slabs byN. Platon. However the majority of the original ones, and especially those that seem to be in their original position, are all made of nodular and lenticular gypsum (Fig.5.188). All gypsum elements of this area have been registered on Hood's plan and catalogued (*KN*218-377) but apart from the variety there are no other significant features worth mentioning.

South Corridor and Porch

Finally, the southern most part of the palace including the South Porch, South Corridor and the South Façade is the last section that was examined (Appendix 1: Plan 2 and 11).

The **South Corridor** that connects the South-West Porch with the South Porch, preserves very few remains of burnt selenite paving slabs that can be seen at the east end of it. Evans refers to this corridor as a veranda that had a central causeway of gypsum slabs, presumably flanked by irregular limestone pavement on either side (Evans 1921:209). He reconstructed a row of rectangular paving slabs of which only the first and the last (*KN*133 and *KN*139) have original fragments of burnt selenite slabs embedded in the concrete (Fig.5.189). Another two slabs of burnt selenite are south of the east end of that corridor (*KN*140 and *KN*141) set in concrete.

West of the South Porch' is the South Façade' consisting of double orthostatic gypsum walling set on a limestone *krepidoma* (Evans 1921:208-209, Fig. 154). The outer and lower wall, of which only three selenite orthostates are preserved (*KN*144-146) probably served as a massive terrace wall that supported the South Corridor. Like in the West Facade the orthostates here consist of selenite that is cut and placed so that the crystals are vertical. The half upper part of the orthostates is burnt and heavily weathered while the lower part, although cracked, preserves the original characteristics of the stone (Fig.5.190).

Another two large ashlar blocks are on the west wall of the **South Porch** (*KN*142 and *KN*143) which is in general smaller and simpler than the West Porch with a small 'warder's lodge' (Evans 1921:215). Although these are totally burnt and much dissolved, the doorjamb (*KN*130) that is sitting next to the north one is not affected by fire at all and probably belongs to a later phase. The same applies to the other doorjamb of the doorway (*KN*128) and the one next to it (*KN*129) that is in secondary use (Fig.5.191). The paving slabs of the threshold are missing and are restored in concrete. Along the South Corridor are the remains of the orthostates of the inner wall of the South Façade. The orthostates of the inner wall are again made of selenite and are mostly burnt (Fig.5.192) apart from one (*KN*119) that is partly unaffected (Fig.5.193). Some of the orthostates at the west end of the wall are totally stained black, sitting next to white ones showing a very different firing pattern and it seems that they are not in their original position or the position they had at the time of the conflagration (Fig.5.194). Fire marks in general are not expected to be uniform along the entire length of a wall but nevertheless a smooth transition from one state to another is anticipated and can be recognised and traced on many walls. The blocks that are sitting on top of the first course are not in their original place either. They are either in secondary use or were placed there by Evans. Most of the gypsum blocks of the inner side of the facade are burnt as well and do not follow an obvious architectural line. Only one of them is in an upright position while the others are upside down and in general their finished surface is not aligned with the face of the wall.

5.2 Megaron Nirou

The LM IA Minoan Villa known as Megaron Nirou is a small building (1000m^2) with palatial characteristics and an exceptional character as indicated by the finds and the architecture (Fig.5.195). The building is close to the port of Nirou Khani, is only seven miles (13 kilometres) away from Knossos by sea, and could be reached from Knossos via both sea and land routes. The land route that Evans suggested is the following: "the Minoan Road would have probably skirted the rocky headland of Kakon Oros, then pursuing its way across the rich level country that lies about the lower course of the ancient Karteros, past the site of Mation, and so by the natural pass, lined with late Greek and Roman rock tombs an once doubtless followed by the Roman road. From this point it would join the Kairatos valley and reach Knossos somewhere near the spot where the piers of a Roman bridge are still preserved by the N.E. extremity of the Minoan town" (Evans 1928:280, foot note 2). The port may have served as a 'maritime outlet' of Knossos, as Evans noted, which can explain the strongly Knossian character of its architecture. However as regards the transportation of building stone from Knossos to Megaron Nirou, we have to consider that the most convenient route would be via sea.

The building exhibits characteristic palatial architectural features such as paved court with causeways, 'Minoan hall' with *polythyron* and portico, light well, a gypsum bench and a considerable amount of architectural gypsum. The ritual character of the building is already evident in the paved courtyard with the large pair of 'horns of consecration' and a raised base probably intended for a cult symbol, perhaps a double axe. The discovery of four large bronze axes in Room 7 (with an average width of a metre), four lamps with pedestal in Room 14 and the piles of tripod hearths or altars closely stacked in Room 18 (offering tables), all related with ritual ceremonies confirms the ceremonial character of the building, which the excavator interpreted as the official ceremonial building of the settlement that is related to it, perhaps the 'headquarters' of 'High Priest' (Xanthoudidis:1922:1-25, Evans 1928:280-285, Graham 1962:58-59, Betancourt 1997:96-97). Koehl (1997) on the other hand interpreted a group of rooms as the ancestor of the historical Cretan *andreion* with a *koimitirion* (Room 15 with bench), a communal dining area (Room 12 with bench) and sufficient storage space and lavish interior decoration. Whhatever the function of the building, its outstanding character well demonstrated, by the architecture and the movable finds, was the reason for the transportation of ornamental stone from the quarries of Knossos.

Distribution of gypsum in Megaron Nirou

The total volume of gypsum used in Megaron Nirou is small (a minimum of 4.8m^3) but it covers a rather large surface (a minimum of 22m^2) considering the size of the building (Fig.5.195). It was mainly used in slabs for dressing walls, floors, benches and staircases. The only structural gypsum in the building is found in doorjamb bases. Although Nirou Khani has used the smallest quantity of gypsum, the great majority of it is found in a good context and allows a detailed account of the different morphological varieties, and their use in architectural design. About 93% of the preserved material is found in situ in primary context and another 7% is found as loose slabs, fallen from the upper storey or from the upper parts of the walls of the basement. It is almost certain however, that some of them have fallen from the upper floor, since their thickness, identifies them as paving slabs and not wall dadoes. The fact that the building was abandoned after its destruction and therefore the original context is not disturbed by later modifications, along with its convenient size, makes it an convenient case study on the use of gypsum. Furthermore, the diversity of gypsum varieties used in the building allows the comparative study of weathering forms in the different varieties under the same exposure.

The gypsum varieties that are used here are exactly the same as those of the Domestic Quarter of Knossos and are used in a very similar manner (Fig.5.196). There is no doubt that stone was brought from the Knossian quarries. Furthermore, as will be demonstrated below, it was worked and applied in the same fashion. Selenite with an average crystal size of 2-3mm is used for doorjamb bases, floor slabs, and staircase treads (marked blue in Fig.5.196). The nodular and lenticular gypsum cut both transversal (marked with red in Fig.5.196) and vertical to the laminations (marked with green in Fig.5.196) is restricted to the main hall, half or Corridor 11 and the bench in Room 12.

The gypsum floor pavement in **Hall 2a** resembles the floor of the Queen's Megaron and the 'Room of the Throne' at Knossos (Fig.5.197 and Appendix 1: Drawing 26). The floor slabs (*NH*83-85 and 87-103) consist of nodular and lenticular gypsum that is cut parallel to the laminations and displays grey-brown wavy veining (Fig.5.198) with the exception of one slab at the north-east corner (*NH*86) that is purely laminated gypsum, the typical variety of Phaistos and Agia Triada (Fig.5.199). However it is not unusual to have small occurrences of this material within the nodular and lenticular beds of gypsum, as can be seen at the outcrops of Foinikia and Tsangaraki. The laminated gypsum is definitely not stratified here in large quantities for exploitation but the presence of a layer that produced a slab of solid laminated gypsum does not really change very much the broad picture. The slabs are placed on the floor so that they form three concentric rectangular frames, which is a common feature in most Minoan floor pavements, often enclosing a different stone of contrasting colour in the middle as in Room 5 and Room 12 of this building.

On the south the hall opens to **Portico 2** through a four door *polythyron* with selenite doorjamb bases (Fig.5.200). The thresholds of the doorways are paved with the same slabs as the hall. The west, east and south walls were also dressed with dadoes of the same variety, of which only those of the east wall (Fig.5. 201) and one on the north are preserved to a significant height of nearly a meter while on the west wall are various fragments of broken dado slabs set in random in a restoration attempt (Fig.5.202)

The same variety but cut in a different direction, vertical to the laminations of the stone is used for part of **Corridor 11** on the north of Hall 2a that leads to Room 12 (Fig.5.203 and Appendix 1: Drawing 27). A similar scheme to that in the 'Domestic Quarter' of Knossos where the same stone worked in the same way is again restricted to a part of the Dog's Leg Corridor and the part of the Lower East-West Corridor in the Hall of Colonnades. The rest of this corridor as well as **Corridor 4** is paved with selenite or banded selenite (Fig. 5.204 and Appendix 2: Drawing 28)

The floor of **Room 12** is paved with selenite that encloses a central compartment of bluish-grey limestone (Fig.5.205 and Appendix 2: Drawing 29). The base of the bench that is built against the south and west walls of the room is made of nodular and lenticular gypsum of which the pilasters show surfaces vertical to the laminations and the *metopes* show surface parallel to the veining, whereas the top is made of selenite (Fig.5.206).

Similarly the floor of the **Room 5** is paved with a central compartment of irregular bluish-grey limestone enclosed by a frame of selenite slabs (Fig.5.207-5.208 and

Appendix 2: Drawing 30). The walls were originally dressed with gypsum dadoes of which very few remains are preserved (*NH*28-30). Judging from these few remains the dadoes of this room must have been originally made of selenite that is now burnt to opaque white. In **Room 6** (Fig.5.209 and Appendix 2: Drawing 31) the walls and the floor are all dressed with selenite slabs, the majority of which remain unaffected by fire and preserve the original crystallographic characteristics of the stone (Fig.5.210-5.211). Apart from this room the rest of the gypsum of both varieties is affected by fire. Finally the top slab of bench in Room 15, although poorly reserved, is also made of selenite.

The gypsum slabs are all broken and have suffered considerable dissolution, although the building is sheltered. Dissolution caused by concentrated flow of water that is dripping through the shelter is the most prominent active weathering process, and will be described in detail in Chapter 5. Apart from the gypsum that is found in situ there are several fragments that were found in the rooms during excavation which were all examined, numbered and photographed. Xanthoudidis (1922) suggested that there was a second floor as indicated by the existence of a staircase and that there were gypsum decorations similar to those of the ground floor. He refers to fragments of a second bench that were found in Room 12 and probably belong to a bench that was above this room. I have not been able to identify any bench fragments within the piles of loose slabs but there are definitely lots of floor and dado slabs that must have fallen from the upper floor. The measurements that were taken from the loose slabs were included in the calculation of the total volume of gypsum so that we can have an idea of the bulk of the material that was transported from Knossos for the execution of this building project.

5.3 Phaistos

Gypsum was already used at Phaistos in the Early Palace for dressing floors, walls, and benches and for cut staircase treads (Fig.5.212-5.215). The floor slabs however are not as regular as those of the New Palace and the benches are not as elaborate. I have not seen any structural gypsum in the Early Palace of Phaistos and even the orthostates of the West Façade, set on a projecting *krepidoma* (Fig.5.216) and very similar to those of the West Façade of Knossos, are made of limestone instead of selenite (Shaw 1973:83-88, Shaw 1983).

In the New Palace, although gypsum is used in a greater extent and for multiple functions, its decorative character is maintained (Fig.5.217). The variety of gypsum used at Phaistos is a laminated one, in white to light brown hues, usually referred to as 'balatino', which has been described in Chapter 3. It was probably obtained from the nearby outcrop that was discovered by Pernier and Banti in 1900 south west of the palace (Pernier 1951:419). When cut vertically to the veining it shows a banded surface with almost parallel veins (Fig.5.218) while the transversal section shows a multicoloured surface with wavy veining (Fig.5.219). As already mentioned in Chapter 3 it is very similar to the nodular and lenticular variety when the latter is affected by fire but it should not be confused as the original characteristics of these varieties before fire were quite distinct.

Primary selenite, the main variety that is used for structural purposes at Knossos, is not found at all at Phaistos, which is not surprising since it does not occur in the neighbouring outcrops either. Perhaps the lack of selenite is the reason for the use of limestone for the orthostates, since the fine grained laminated gypsum of Phaistos would not resist very much in an outdoor environment and is indeed restricted to the interiors or open but roofed areas (i.e. porticos) areas in both Early and New Palaces.

The volume of gypsum that was used at Phaistos is far less than that of Knossos (about ten times less) reflecting mainly the absence of gypsum from structural elements such as orthostates, ashlar, large jambs and pillar blocks. Also in the west magazines of Phaistos there is very little gypsum in comparison to the Knossian ones that were almost entirely dressed with gypsum slabs including the cists that are also absent here. However as regards the decorative aspect, gypsum performs all the usual functions that have been described at Knossos: floor slabs, wall dadoes, bench lining, coping of balustrades and staircase treads. It is mainly found in the Grand Propylaeum at the west entrance (68), in the 'Domestic or Residential Quarter' (76-85, 50-51 and 63), the porticos of the 'Peristyle Court' (74), in the lustral basins (19,21) in rooms of social character with sitting areas (23,24), in the Vestibule of the Magazines (25) and in a few magazines (33,38,88) (Fig.5.217).

It should be noted, however, that my observations at Phaistos are based on the 60% of the total volume of the existing gypsum. Another 40% are either covered with a thick layer of soil or have been replaced with modern gypsum slabs. The original gypsum floors of the residential quarters, Vestibule 25 and partly of Room 93 were cleared out in 1951-1955 and replaced with new ones obtained from the Minoan Quarry of Agia Triada (Shaw 1973:42-43, fig.33, D.Levi1976:1-5).

Distribution of Gypsum in the Palace of Phaistos

In this section I will describe the architectural gypsum of the New Palace of Phaistos without reference to the variety or the chronology since the entire volume of gypsum consist of one variety that is 'balatino' or 'laminated gypsum' in cream to light brown hues, installed in the same building phase (MMIII/LMIA). The room reference numbers that are used are those of Pernier as marked in the plan of the site (Fig.212). The gypsum catalogue numbers have also been marked on the same plan while elevation sketches were drawn for all the gypsum that is not shown in the plan and are included in (Appendix 1: Plan 13-17, Drawing 34-44)

As we enter the palace from the West Court the first gypsum remains are found in the first room of the **Grand Propylaeum** that consists of two porticos (68 and 69) and the large **Light Well 69A** (Pernier 1951:313-321) (Appendix 1: Plan 13). Gypsum was used here for the pavement of **Portico 68**, the large jambs and pier bases (*PH*404-405, 411-413, 416-417), and the thresholds (*PH* 406-409, 414-415) that formed the entrance to the inner **Portico 69** (Fig.5.220). Very few remains of the pavement are preserved, while the top of the pier and the doorjamb bases is covered with cement. The slabs that are used here are all cut and placed in a direction parallel to the laminations of the stone (Fig.5.221).

At the south wall of Portico 69 is the entrance of **Room 70,** with gypsum pier blocks (*PH*419, 423) and three steps (*PH*420-422) (Fig.5.222), a feature that, as we have seen, is quite common at Knossos, where almost all doorways and passages have gypsum doorjamb bases on either side and gypsum thresholds or steps. At the north-west corner of the room there are remains of a low rubble structure with gypsum pilasters that indicates the existence of a bench that probably ran along the north wall and was dressed with gypsum, probably in a similar fashion as those in Room 23 and 24 (*PH*424-428 in Appendix 1: Drawing 34). Pernier (1951:327) has suggested that this room may have served as a 'Porter's Lodge' for a guard that controlled the entrance to the palace.

A second doorway on the north wall of Portico 69 led to the **'Peristyle Court 74'** through **Staircase 71** and **Corridor 73**. At the entrance there are two L-shaped gypsum doorjamb bases (*PH*381-382) and a threshold paved with three gypsum slabs (*PH*383-385) (Fig.5.223). The landing (*PH*386-390) and the treads (*PH*391-403) of the staircase are also paved with gypsum (Fig.5.224). The staircase is divided in two ramps, of which the lower consists of three steps while the upper preserves another four. Two steps of the upper ramp (*PH*397-398) are made of single blocks of gypsum that are 2,65m long (Fig.5.225). Unfortunately this part of the palace is all exposed to the rainwater and open to the visitors and therefore the gypsum remains have been subjected to severe dissolution and abrasion of the surface. Between the first and the second ramp there is a passage with two large gypsum pier blocks on each side, which opens to Corridor 73.

The pavement of **Corridor 73** is mostly covered with soil but the few slabs that are visible at the east part of it are quite irregular and are drawn as such in Pernier's plan (Fig.5.226-5.227). Pernier (1951:339) also mentions that the pavement of the west part of the corridor was completely destroyed. He also refers to gypsum fragments that were found in **Room 72** that were probably fallen from the staircase above (Pernier 1951:337).

The east end of Corridor 73 opens at the south west corner of the **'Peristlyle Court 74** (Appendix 1: Plan 14, Drawing 35). The court is enclosed by porticos on its four sides that were paved with gypsum slabs of which only few are preserved mainly in the west and less in the north and the south portico. A six door *polythyron* on the north connected the court with the rather large **Room 93** which is paved with rectangular gypsum slabs set in a rhomboidal pattern that is a unique example of such a pattern in Minoan Crete.

The slabs are framed with red painted plaster (Fig.5.228). The doorjamb bases of the *polythyron* were made of gypsum but most of them are now reconstructed with concrete (Fig.5.229). The laminated gypsum that is used here has a light colour in off white-cream hues and perhaps resembles alabaster more than any other architectural elements that have been examined on the course of this study (Fig.5.230). The west wall of the west portico and of Room 93 was veneered with gypsum dadoes that are preserved to a maximum height of 87cm. Two niches are formed along this wall, one in Room 93 and the other in the west portico, both paved with gypsum (Fig.5.231).

On the south of the peristyle court is **Vestibule 75** which according to Pernier (1951:357) was paved with gypsum slabs of which very little was preserved and nothing is visible at present. Pernier interpreted the above group of rooms (93, 74 and 75) as reception areas. A staircase at the north-east corner of the Peristyle Court descends to a complex of rooms, built against an artificial cut along the north edge of the hill, that is known as the 'Domestic or Residential Quarter' and shows many similarities with the equivalent 'Domestic Quarter' of Knossos (Pernier 1951:260-304, Graham 1959).

Domestic Quarter

Here the 'Domestic Quarter' is located on the north of the Central Court instead of the east and does not have direct access to it. The domestic quarter includes a large hall with polythyra (79) porticos and light wells (77, 78, 85), private rooms (81, 82) and a bathroom or lustral basin (83) (Appendix 1: Plan 14a). A separate section that is considered as part of this unit is Room 50 with low benches along the south and east wall and a double on the east which opens to a light well. Corridor 51 behind the north wall of Room 50 leads to a staircase that was presumably serving the upper floor. The entire complex was dressed with gypsum slabs including floors, walls, benches and staircases (Fig.5.232). However, very little of the original gypsum fittings is preserved at the present. The majority of the original wall dadoes are, missing apart from few remains at the lower part of the walls that are reconstructed with concrete while the floor slabs as, already mentioned, were replaced with new ones in 1955 by Levi using gypsum from the Minoan quarry of Agia Triada (Graham 1959:49, n.15, Shaw 1973:42-43, Fig.33, Levi 1976:3-6, Fig.5-10). The area that is paved with gypsum is marked with red in (Fig.5.232). The modern slabs are marked with red colour in Appendix 1: Plan14a. Photographic documentation of the original floors before restoration is available at the archive of the Italian School of Archaeology in Athens and a series of representative photos that were acquired for the purposes of this study are presented here along with the present pictures. Some photos were also published by Levi (1976:4-5). It should be stressed here that the variety of gypsum that was used during the restorations for the replacement of the floor slabs is a chaotic selenite that is very far from the original variety as regards its petrographic and macroscopic characteristics. In addition, the modern slabs were quite unsuitable for paving floors as most of them very soon developed severe deformations and detached from the floor (Fig.5.234).

The following structural and decorative gypsum components are found in the domestic quarter: the treads and the landing of **Staircase 76** (Fig.5.233), the pavement and the south walls of **Portico 77 and Hall 79** (Fig.5.234-235, 5.237-5.238), the south wall of Light Well 78 (Fig.5.236), the west wall of Hall 79 and **Light Well 85** (Fig.5.237-5.239), the pavement of Light-Well 85 (Fig.5.235), the pavement and the walls of **Corridor 80** (Fig.5.240), the pavement and the walls of **Room 81** (Fig.5.241-5.243), the staircase pier and treads as well as the floor and the walls of **Lusrtal Basin or**

Bathroom 83 (Fig.5.244), part of **Room 82** (Fig.5.245) the doorjamb bases of the polythyra and of the doorways, the pier block (*PH*40) at the north-east corner of Hall 79 (Fig.5.246) as well as the piers (*PH*246-247) at the entrance of Room 50 (Fig.5.247-5.248), the pavement, the walls and the benches of **Room 50** (Fig.5.249-5.251) and finally the pavement of Corridor 51 and the treads of the staircase that leads from the corridor to the upper floor (Fig.5.252). The benches and the wall dadoes of the domestic quarter are all drawn and numbered in the field notebooks (Appendix 1: Drawing 36-38).

The most interesting amongst the original gypsum remains of the 'Domestic Quarter' are the dadoes of the balustrade of **Lustral Basin 83**(*PH*201, 204, 206) and the slab (*PH*195) that paves the raised space east of the lustral basin and is entered from a separate doorway at the east end of the south wall of Room 81. These are all made of laminated gypsum with colourful veining in red, orange and brown hues and remind one of the colourful gypsum of the Villa at Agia Triada. Although pinkish gypsum has been seen at the outcrops, in this case the colour has been enhanced by fire that oxidised ferrous inclusions of the laminations. This is evident on the lower part of dado (*PH*206) and pier (*PH*203) where the core of the rock as revealed after dissolution of the surface has apparently lighter colour than the outer surface (Fig.5.253).

West Wing

In the west wing of the Palace, gypsum is found in Staircase 39, Vestibule 25, in the West Magazines and in various small rooms of the south-west quarter.

The entrance to **Staircase 39** has gypsum doorjamb bases and a threshold while the staircase itself is built with gypsum treads of which very little is preserved. The staircase is divided in two ramps for which Pernier made a remarkable note on the different height of the treads and the wear and tear marks which imply different use of the two parts of the staircase. He also notes that each tread is a single piece of stone 2.00-2.10m wide (Pernier 1950:76-77). However none of these observations could be verified on site today due to the severe weathering of the entire structure (Fig.5.254)

In **Vestibule 25**, the south, west and north walls of the room were decorated with gypsum wall dadoes (*PH*472-483) with a maximum preserved height of 0.45cm on the west wall (Appendix 1: Plan 15 and Appendix 2: Drawing 39). The floor is also paved by rectangular gypsum slabs that are arranged in a double concentric square motif and are outlined by red mortar. In the centre of the room the floor slabs form a band, east–west oriented on which are installed two gypsum column bases (*PH*468 and 469). The original floor slabs were removed by Levi in order to excavate underneath and were replaced by new ones that were cut to the dimensions of the original ones (Fig.5.255-4.257). Only a few of them (*PH*462-464 and *PH*470-472) are visible today as most of the pavement is covered by thick layer of soil (Fig.5.258). Gypsum also paved the floor of the niches of the west, south and north walls and the frame of the small window on the north wall between the niche and the doorway to Staircase 39 (Pernier 1951:72-75).

A double doorway on the west wall of the vestibule led to the main corridor of the storerooms with a series of magazines on either side. Apart from the doorjamb bases and the thresholds of the entrance there are no other traces of gypsum preserved in the main corridor. The large doorjambs of the magazines are made of limestone instead of the gypsum ones that we saw at Knossos apart from **Magazine 32,** which is entered from Corridor 7 and which preserves the gypsum doorjamb bases and the threshold of the entrance. There are no remains of the floor pavement or wall revetments and it seems that gypsum was not used here to an extent comparable to that of the West Magazines of Knossos. Pernier also mentions that in **Magazine 37** there is an 'in situ' pithos that is placed on a gypsum slab. However there are no other remains of gypsum preserved on the floor of this or any other magazine apart from 33.

Magazine 33, that is the best preserved magazine, contains a considerable amount of gypsum fittings (Appendix 1: Plan 15, Drawing 40). The threshold of the entrance and the floor are paved with gypsum slabs that are framed with red plaster. At the centre of the magazine the slabs form a central panel with smaller slabs which are 10cm higher than the rest of the floor pavement. The floor and the walls show clear evidence of conflagration (Fig.5.259).

A considerable amount of gypsum is also found in **Magazine 38,** which dates to the first palace (MM) and was modified and used again in the New Palace period. The floor is paved with gypsum slabs, the level of which is 50cm lower that the floor of Vestibule 25. The west wall was dressed with gypsum dadoes with a maximum height of 0.5 m. It is quite interesting that within the little corridor in the storeroom there is a wall of the first palace that preserves remains of gypsum dadoes as well. The floor of Magazine 38 seems to extent under the Staircase 39 that belongs to the New Palace period (Pernier 1951:96-102).

Immediately south of the magazines there is the wide corridor that leads from the Central Court to the West Court. The pavement of **Corridor 7** is drawn in the plan and described by Pernier but it was later removed in order to excavate underneath (Appendix 1: Plan 15). According to Pernier's description (1951:45) a causeway 1.40m wide was formed by regular gypsum slabs that run along the entire length of the corridor at its south half, while the rest of the pavement on either side of causeway consisted of irregular gypsum slabs. A similar scheme has been seen in the West Porch and the Corridor of the Procession Frescoes at Knossos only that in this case the irregular slabs around the causeways consist of limestone or schist. Pernier also refers to remains of gypsum dadoes on the walls of the corridor which are again no visible at the present (Pernier 1951:44).

The **South West Quarter** of the Palace constitutes a complex of small rooms, corridors and two lustral basins most of which were dressed with gypsum floor slab and dadoes as well as staircases and benches. Due to the great loss of material and the poor state of preservation of the remains it is not easy to understand to what extent it was used in this part of the building (Appendix 1: Plan 15). In this sector gypsum is found in the following rooms:

Room 8: the L-shaped doorjambs of the entrance are set on roughly cut limestone foundation, as well as the floor of Room 8 of which very few remains are visible close to the east and west doorways.

Room 10: the two benches on the north and the south walls were most likely dressed with gypsum as any other bench occurring in sites where gypsum is used in architecture. Few gypsum slabs are still preserved at the east end of the south bench. The floor was also paved with gypsum slabs of which only a few traces are preserved in front of the south bench.

Room 11: the doorjamb bases of the doorway from Room 10 to Room 11.

Corridor 12: The doorjamb bases and thresholds on both north and south doorways of the corridor. The threshold of the south door is not preserved but the north preserves part of the threshold with the hole that held the door. The corridor itself would normally be also paved with gypsum slabs but there are no visible remains or reference in Pernier's description (Pernier 1951: 118)

Room 13: The doorjamb bases at the doorway that leads to corridor 14.

Corridor 14: the walls of the west north-south axis of the corridor were dressed with gypsum dadoes of which the maximum preserved height is 0.90m (Fig.5.260) (Appendix 2: Drawing 41-42). The floor does not show any traces of gypsum pavement but it should have one originally (Fig.5.261). The east–west axis of the same corridor is also dressed with gypsum slabs while in the second (east) north-south axis of the same corridor that is parallel to the first there are only the gypsum doorjamb bases of the doorway. No traces of it are mentioned by Pernier (1951:120) and it is uncertain whether this second and longer corridor was also paved and veneered with gypsum.

Rooms 15-18: all the doorjamb bases of the doorways that connect one room to another and a base of a wall pier in Room 16. The doorjambs from Room 15 to Room 17 are made of gypsum as well. Room 15 also connects to Room 16 with a doorway that preserves its gypsum doorjamb bases and the base of a wall pier.

Lustral Basin 19: a staircase with four treads leads into the sunken area of Lustral Basin 19, each tread made of a single piece of gypsum (width: 0.97-1.03m). The staircase parapet has gypsum pier and coping slab (Fig.5.262) (Appendix 2: Drawing 41). There are no remains of gypsum dadoes or floor slabs but it is almost certain that the lustral basin would have been entirely dressed with gypsum. Since the preservation of the material at the site is so poor, it is not surprising that gypsum slabs that would be expected to be found at certain structures are missing. In some cases such as the lustral basins we can assume that the parapet of the staircase, the floor and the walls would originally be dressed with gypsum slabs as has been repeatedly seen at other better preserved examples at Knossos and the North and East Wing of this palace.

Room 20-21: the doorjamb bases of the door way from Room 20 to 21.

Lustral Basin 21: a staircase with gypsum landing and three treads, each consisting of a single block of gypsum 90cm wide leads into the sunken area of the lustral basin. As in Lustral Basin 19 the staircase parapet has a pier that consists of a single block of gypsum but there are no remains of coping, floor or wall dado slabs (Fig.5.263 and Appendix 2: Drawing 42).

Room 22: there are two doors on the south wall of this room, of which the western has one gypsum doorjamb and probably had a second one, while the east door has limestone doorjamb bases and threshold instead of the usual gypsum ones.

Rooms 23 and 24: these rooms are characteristic of the architecture of Phaistos. Their layout reminds of the Anteroom to Room of the Throne Room at Knossos but here the two rooms are independent and they do not have the characteristic Minoan *polythyron* connecting them. It seems that those rooms had a public character probably for small scale meetings.

Room 23: gypsum benches are built against the west and the north walls (Fig.5.264). The benches are 40cm high and the seat is 40cm deep (Appendix 2: Drawing 43). The core of the benches consists of a rubble structure against which are set gypsum slabs that are about 6cm thick. The sides of the bench are dressed with gypsum slabs that alternate with square panels or *metopes* (0.31x0.31x0.33m) that are 8cm thick and have *triglyph* decoration (Fig.5.265). Pernier described the construction technique of these benches with piers forming the corners and alternating interlocking *metopes* and pilasters with *triglyph* decoration at the front and published a section that shows how they connect (Fig.5.266). The *triglyph* decoration is barely visible today but there are good photographs of it in the publication of the site by Pernier (Pernier 1951:146-48, Fig. 86-88). It is apparent in these photographs that the panels with *triglyph* decoration are not always vertical and alternate with plain slabs or *metopes* (Fig.5.267) (Pernier 1951:146-149).

These are in general some of the most heavily weathered gypsum slabs that have been recorded in the course of this study. The combined effects of rain water and biological growths have resulted in a quite obscure picture and it is not possible to observe any surface details (Fig.5.268). The floor of the room was also paved with gypsum slabs which are not preserved except for a few traces close to the bench.

Room 24: the entrance to the room is paved with a gypsum threshold and two L-shaped doorjamb bases (*PH*506 and 507) (Appendix 2: Drawing 43). The threshold is not preserved but is mentioned by Pernier (1951:149). A later wall that was added to the south and narrowed the room had a doorway with L-shaped gypsum bases as well. A bench runs along the west, the north and part of the east wall (Fig.5.269). The core of the bench is again made of a rubble structure that was then dressed with gypsum slabs. The top slabs that form the seat are about 7cm thick. The majority of the bench slabs are reconstructed with concrete while the remains of the original material are heavily weathered like those of Room 23. The missing part was measured and its volume was included in the calculation of the total volume of gypsum used in the building. The original remains of the bench of this room are clearly shown in Pernier's publication of the palace (Pernier 1951: 150-151, 153 Fig. 90-93). Another interesting feature that is clearly seen in these pictures is that the doorjamb bases are quite higher than the usual.

The floor of the room was paved with irregular gypsum slabs of which very few traces are preserved to the present. The small room that is formed by the later wall that narrowed the main Room 24 has a gypsum pier in its south-west corner that also forms the north-west corner of Room 23.

Rooms 95 and 95′: the north side of these rooms there is a five door *polythyron* with gypsum L and T shaped doorjamb bases (*PH*593-598) but no threshold slab are preserved in between the jambs (Fig.5.270). Pernier found here gypsum staircase treads probably fallen from the upper floor (Pernier 1951:130).

Room 96 and 96′: there are a couple of gypsum doorjamb bases at the entrance of Room 96. Another couple of doorjambs are built into the wall that divides 96 and 96′ that was originally a doorway.

Corridor 97: is paved with gypsum slabs that are roughly shaped and are shown in Pernier's plan but were not visible at the time of this field study either because they have been totally lost or were covered with soil.

In the sector that is immediately north of the Central Court and south of the Domestic Quarter gypsum is found in the doorways, a few floors and Staircase 42 (Appendix 1: Plan 14). The treads and the landing of the staircase are made of gypsum as well as the pavement of the corridor in front of the staircase (Fig.5.271). The first seven treads of the staircase (*PH*691-696) are partly preserved, while another six are restored with concrete. In Corridor 43 next to the south of the staircase there are remains of gypsum slabs which Pernier (1951: 244) thought that may have fallen from the staircase. Traces of a gypsum floor pavement are preserved in Rooms 46, 47, 59, and 60. There are some gypsum slabs embedded in the pavement of Corridor 41 that consists mainly of irregular limestone slabs but are probably on secondary use, placed there on the course of some restoration phase. Another gypsum slab was also found in Room 45, but it was not in situ and had probably fallen from the upper floor (Pernier 1951:249). Gypsum doorjamb bases are found at almost all entrances of this sector: namely at the entrances of 42-46, 57-61 and 92 (*PH*692-710 and *PH*722-732) (Fig.5.272). The gypsum doorjambs of a two door *polythyron* that was blocked in a later phase of the second palace can be seen at the lower part of the west wall in Room 59 (*PH* 701-703).

Room 88 has a gypsum floor pavement and two staircases with gypsum treads. It belongs to the first palace and its floor is at a lower level than the Neopalatial structures (Appendix 1: Plan 16).

Room 89 which is Neopalatial and partly built over Room 88, was also paved with gypsum slabs that are poorly preserved in fragments.

East of Rooms 88 and 89 and North of the East Court is **Room 53**, which may have functioned as porter's lodge, also paved with gypsum. Along the west, north and south walls there are benches that would have been dressed with gypsum but only few remains are preserved on the south bench.

East Wing

Finally, in the East Wing of the palace there is **Portico 65** and a group of **rooms 63-63d** and **64** that are clearly of exceptional character as evident by the architectural characteristics and the luxurious interiors (Appendix 1: Plan 17). However, these rooms are poorly preserved and it requires the mind's eye in order to understand their original appearance. At the north end of **Portico 65** and in front of Room 63 there are two structures that were used as baths or water tanks and two benches attached on them

(Fig.5.273). The exterior of the tanks was dressed with gypsum and the interior with plaster. The south bench is better preserved and shows clearly the technique that was used for its construction. It is made of gypsum and rubble: the corners of the bench are formed by two piers set (*PH*624and 625) on a slab (*PH*622) (Fig.5.274) that have small projections in order to hold a vertical *metope* (*PH*624) that forms the front of the bench (Appendix 2: Drawing 44). The top (*PH*626) and the back (*PH*628) of the bench are formed by two slabs. The top slab is about 7cm thick while the back is only 3cm. It seems to me that the same technique is used for all benches here and at Agia Triada and for most benches at Phaistos and Knossos.

A gypsum staircase leads from the Stoa 65 to **Room 63** or (Hall 63) that has the typical layout of a Minoan hall with two *polythyra*, one dividing the room and a second opening to **Portico 64** on the east (Fig.5.275). As evident by the few gypsum remains, the floor pavement and the wall dadoes of the hall were made of gypsum, as well as the doorjamb bases of the *polythyra* and the doorways. In Portico 64 there are no visible remains of gypsum pavement but Pernier refers to gypsum fragments that were found close to the north wall and were probably parts its dadoes (Pernier 1951:181). According to the typical scheme of the interior design as manifested in all elite building that make use of gypsum, the floor of the portico as well as the wall should be dressed with gypsum slabs. South of Hall 63 is the **Anteroom to the Lustral Basin 63b** the **'Lustral Basin 63d** and the possible **Latrine 63e**. In 63b and 63e gypsum is found only as doorjamb bases while in the lustral basin is applied to the entire interior space; the treads and the pier of the staircase as the well as the wall dadoes and the floor (Fig.5.276 and Appendix 1: Drawing 44).

5.4 Agia Triada

The 'Minoan Villa' of Agia Triada is situated about 3km west of the palace of Phaistos (Fig.5.277). It is a rather large building that dates to the LMI period and includes residential areas, a main court and substantial storage areas (Fig.5.277-5.279). The villa has often been associated with the palace of Phaistos and was originally considered as the 'summer palace' of its ruler (Halbherr *et al.* 1977:50). Due to its size and layout Agia Triada is reminiscent of the true palatial buildings. It has a west wing with public, residential and storage areas and an east wing with similar functions which is the reason that led some scholars to the conclusion that the building comprises of two separate villas (Watrous 1984). For the purposes of this study the villa was examined as a single building and is divided in the sections that are indicated by the excavators: North-West Quarter, South-East Quarter, Magazines East of the North-West Quarter, and the East Quarter. In the South-West Magazines gypsum has not been used at all, apart from one slab that was found in Room 39 which is not securely in place.

Distribution of gypsum in Agia Triada

The villa is known for the luxury of its interior decorations and the rich finds. The interior spaces of the villa of Agia Triada exhibit some of the most attractive gypsum fittings as well as high quality frescoes. Gypsum is lavishly used here for staircase treads, wall and staircase piers, doorjamb bases, thresholds, floor slabs, wall dadoes, and benches (Fig.5.280). The variety of the rock is the same as at Phaistos (laminated gypsum) but exhibits more colourful surfaces (Fig.5.281-5.282). As discussed in Chapters 3 and 4, the stone has been quarried from the local gypsum outcrop that lies a few hundred meters south-west of the site. However the purple, red and orange hues of the stone could have been enhanced by fire as observed in Lustral Basin 83 at Phaistos. The whole building bears evidence of severe conflagration, especially in the North Storerooms where several gypsum slabs have turned black. The preservation of gypsum here is better than that of Phaistos and all rooms preserve their original gypsum. Some missing parts have been restored with cement but no replacements with new gypsum slabs have been made.

North-West Quarter

This quarter comprises public (3, 4, 11, 12, 49), residential (13, 14, 52-55) and service rooms (15, 16, 45) (Fig.277). As in Megaron Nirou, Koehl (1997) interpreted here a group of rooms as the ancestor of the historical Cretan andreion with a koimitirion or sleeping room (Room 4a with a low platform), a communal dining area (Room 4 with bench), sufficient storage space (Rooms 15 an 16) and food preparation area (Room 45).

Gypsum is abundant in all residential and public rooms while some of it is also found in Room 45 that may have functioned as a kitchen. It is essential to describe this complex of rooms in some detail since they represent some of the most complete original gypsum interiors that have been recorded in the course of this study.

Room 4

This is considered as the most important room of the building, intended to accept guests and visitors (Halberr 1951:69) or for dining as suggested by Watrous (1984) and Koehl (1997) (Fig.5.283, Appendix 1: Plan 18, Drawing 45). It is known as the 'Megaron' which is the name that was assigned to it during the excavation (Halberr *et al.* 1977:69). The west side of the room opens to Light Well 49 through a three door *polythyron* and is furnished with a bench that runs along the east, north and west walls. Gypsum slabs are applied to the floor and the bench as well as the thresholds and doorjamb bases of the *polythyron* and the entrance to Room or Cubicle 4a. The corners of the bench are formed by gypsum piers as seen at the bench of Stoa 65 at Phaistos (Fig.5.284). Halbherr *et al.* refer to alternating ***metopes*** and ***triglyph*** decorations at the front surface of the bench; two ***metopes*** and three ***triglyphs*** at the east and north parts and 3 ***metopes*** and 4 ***triglyphs*** at the south (1977:69). However, I was not able to identify any ***triglyph*** decoration at the front projecting panels of the bench and it does not seem that there were any. The projecting parts are mostly affected by dissolution and some of them show intense dissolution incisions which should not be confused with decoration (Fig.5.285). The walls above the bench are veneered with gypsum dadoes (three on each wall) that are partly preserved and therefore their original height is unknown (*AT*46-54). The slabs of the floor form two concentric squares that are outlined by red plaster (*AT*8-20). The north-east corner of the floor is restored with concrete (white area in Appendix 1: Plan 18).

Room 4a (Cubicle 4a)

At the south-west corner of Room 4 there is a doorway to Room or Cubicle 4a (cubicolo) which is a small rectangular room (3.72x1.54m) with no windows (Fig.5.286, Appendix 1: Drawing 46). The room originally had a door towards the light well on the west wall that was later blocked. The floor and the walls are dressed with gypsum dadoes with a maximum preserved height of 1.38m, measured on the west wall (*AT*66). According to the excavators the maximum preserved height of the dadoes of the west wall at the time of the excavation was about two meters. At the north-east corner of the room there is platform (2.04x0.99m) formed by two gypsum slabs (*AT*61-61) that are raised 6cm above the floor. Due to this platform the room has been interpreted by

Halberr *et al.* (1977:69) and other scholars (Koehl 1997, Watrous 1984) as a resting room or bedroom. The room shows traces of intense conflagration.

Portico 12

Portico 12 connects the main Hall 3 with Light Well 49 and Room 4 and 4a. The north and the south walls were veneered with gypsum dadoes of which only few traces are preserved (Appendix 1: Drawing 47). The floor pavement is mostly covered with soil and is not visible but according to Halbherr *et al.* (1977:80) it consists of a central panel of irregular limestone slabs enclosed in a frame of rectangular gypsum slabs. The central panel as well as the outer frame are outlined by a stripe of red mortar.

Hall 3

Room 3 has the layout of the typical 'Minoan Hall' with two polythyra on the north and the east (Fig.5.287). The east *polythyron* has four doors that connect the hall to Portico 12 and the north has six doors that open to the Portico 11. The last doorjamb base (to the west) of the north *polythyron*, as wells as part of the floor pavement, are missing and have been marked with red parallel lines in Fig.5.280. All the thresholds and the doorjamb bases are made of gypsum except for the easternmost jamb that is made of limestone. A unique feature here is that some of the doorjamb bases have a trapezoid shape. On the west wall there are very few remains of dado slabs that were presumably applied along the entire length of the wall, which is only partly preserved at present (Fig.5.288). Similarly, on the south wall are few remains of gypsum dadoes. Halbherr *et al.* mentions that two of dadoes were fallen on the floor in front of this wall (Halbherr *et al.* 1977:80). The floor slabs are arranged so that they form a decorative pattern. An outer rectangular frame encloses four rectangular panels, each consisting of two slabs, which are divided by a cross that is formed at the centre. The four rectangular panels as well as the outer frame are outlined by a strip of red plaster. The central part of the pavement is missing (Fig.5.280). The floor has been covered with soil and it is not possible to have a clear view of it.

Portico 11

The portico is partly preserved with two axes to the south and the east. The south part connects to Hall 3 while the east wall has a doorway to Room 50. The portico was paved with gypsum slabs with brown-cream veining. Red plaster is outlining the slabs forming parallel rectangular panels (Fig.5.277). The east wall is also dressed with dadoes (*AT*264-268) of which only one is preserved in a considerable height (*AT*267) (Fig.5.289 and Appendix 2: Drawing 47). The rest are just visible as preserved to a height of 5-10cm above the floor. It seems that the dadoes have a lighter colour that the slabs of the floor, in white-cream hues. The doorway to Room 50 has a gypsum threshold and L-shaped doorjamb bases of which the south has square mortises on the top and north was built over by restoration structure. The outer frame of the portico towards the outdoor space is made of limestone as well as the cubic pier of its south east corner, practice that is common in all light wells and porticos at Knossos and Phaistos. On the outer limestone base there are two column bases of which the east is made of purple limestone with white and black veining and the south is made of grey breccia (Halbherr *et al.* 1977:82).

Corridor 50

This corridor connects the spaces of public character that were described above with a more private area on the north (Rooms13-14 and 51-55). The corridor is paved with gypsum slabs that are mostly covered with soil. The east end of the corridor has a doorway to Room 52 with a gypsum threshold and L-shaped doorjamb bases. Another doorway to the south leads to Portico 12 is similarly equipped with gypsum fittings. The north wall of this corridor has a series of niches that open in Room 13 (Fig.5.290).

Room 13

Room 13, north of Corridor 50 is the only passage to the north part of the building, known as the 'Room of the Seals' due to the large number of sealings that were found in it. The room is also known as the 'Room of the Multiple Doorjambs' owing to the doorjambs that can be seen in three sides of the room (Halbherr *et al.* 1977:86). The south wall presents a quite problematic structure that cannot be easily interpreted as cists (Fig.5.290). At the west end of the wall there is a doorway that leads to Corridor 50 and next to it there are horizontal gypsum slabs that are set in a level that is 6cm higher that the level of the floor and are divided by 'false' gypsum doorjamb bases that are placed on top. The structure reminds one of *polythyron* but is in fact the floor of three 'wall cists'. The back of the 'wall cists' was formed by vertical gypsum dadoes that separated them from Corridor 50 and which are not preserved to the present. Halbherr *et al.* (1977:87) suggest that the middle wall cist was a lavatory, based on the 'sink'-like structure that is found under the floor level.

On the north there is a *polythyron* with three doors that connect to Room 51. The east end of the north wall after the *polythyron* is dressed with a gypsum dado that is 1.10m wide and is preserved up to a height of 1.50m (Fig.5.291). The east wall has two doors and two wall cists that are alternating and are all lined with gypsum (Fig.5.292). The north door of this wall leads to Staircase 53. Next to it is a wall cist with opening from Room 14 separated from by Room 13 with a vertical dado of gypsum. A second door follows that leads to Room 14 and next to it is a second wall cist with an opening from Room 52 that is again separated by a vertical gypsum dado. The west wall was also dressed with dadoes (*AT*154-156) of which only the lower parts are preserved (Fig.5.293, Appendix 1: Drawing 48). The floor is paved with gypsum slabs that form a rectangular perimetric frame that encloses two large slabs in the centre, and shows traces of conflagration. The usual red plaster outlines the perimetric frame of the floor pavement and each of the central slabs.

Room 14

This room is known as the 'Room of the Wall Paintings' owing to the large amount of wall painting fragments that were found in it. The north and the south walls are made of mud brick and divided the room from the Staircase 53 and Room 52 respectively (Fig.5.292). The west wall is formed by the doorway towards Room 13 and a wall cist that was described in the same room, all dressed with gypsum slabs. The floor is also paved with rectangular slabs of gypsum which form a rectangular section along the north wall that has almost the same dimensions as the platform (perhaps the base for a bed) that was described in Room 4a. It has been suggested that this section may have served the same purpose (Halbherr *et al.* 1977:92).

Room 51

This room may have been the north entrance of the building that allowed the lighting of Room 13, but only the south part of it is preserved. At the south end of the east wall there is a bench (*AT*168-175) that is all dressed with gypsum and is similar to the bench structures of Room 4 (Fig.5.294, Appendix 2: Drawing 47). It is only partly preserved and was probably part of a longer bench. Opposite this bench there was a second bench built against the west wall of which only a few fragments of its base are preserved. The floor of the room was paved with slabs of bluish schist, outlined by red plaster, which is not a common feature in the Messara area but occurs at Knossos and Megaron Nirou (Halbherr *et al.* 1977:90).

Room 52

This is a small room of which the west wall is formed by two doorways, one towards Room 13 and the other towards Corridor 50 with a wall cist in between that was described in Room 13 (Fig.5.292). The south wall has window that opens to Light Well 49. The floor is covered with soil and it was not possible to identify the material used for its pavement. However, Halbherr *et al.* mentioned that the floor was paved with irregular slabs of gypsum that are outlined by red plaster. A mud brick wall on the north divided this room from Room 14 (Halbherr *et al.* 1977:90-91).

Staircase 53

Staircase 53 descends from Room 13 to Portico 54. It consists of six gypsum steps including the threshold of the doorway from Room 13 (Fig.5.295). The landing at the end of the staircase is paved with limestone slabs instead of the usual gypsum. The doorway towards Room 54 however is again paved with gypsum and has gypsum doorjamb bases. At the east end of the landing there is a wall cist cut into the wall. The wall cist is paved with two gypsum slabs that form a kind of step (Halbherr *et al.*1977:96).

Portico, Light Well and Staircase 54

At the central part of this area there is a light well that was not roofed and therefore limestone slabs were used to border the gypsum paving of the floor on the sides of the open air space. Three column bases are sitting on the limestone frame of which the north is made of green limestone, the corner one is made of purple limestone with white and greenish veining, and the west one is again made of purple limestone. As already mentioned this is a common practice at the light-wells and the porticos at both Knossos and Phaistos and was intended to protect the gypsum floors from the rain water. The gypsum slabs of the floor are rectangular but are not very regular as regards their size (Fig.5.296).

Behind the north wall of the light well is a 'bath like' structure of which the bottom is made of limestone while the north, east and south sides are made of gypsum slabs that are preserved up to a height of 20-30cm (Fig.5.297). It is possible that a fourth slab existed at the west side but there are no traces of it. As a structure it reminds one of the floor cists of the West Magazines at Knossos, but its function is not known although in (Halbherr *et al.* 1977:100) both possibilities of the 'bath' and the 'cist' have been discussed. The north slab of this structure is the back side of the wall cists that form the south wall of Room 55. Next to this structure, to the west, is a doorway with a gypsum threshold and doorjamb bases that leads to Room 55. East of the light well is the staircase that led to the second floor which consists of six gypsum steps, each made of a single piece of stone (Fig.5.298) (Halbherr *et al.* 977:98-100, Fig. 98-100).

Room 55

The walls of the room are not preserved apart from small section of the south west-east corner. The south wall is formed by the doorway towards light well 54 and two 'wall cists' raised from the floor and dressed with gypsum, that are in general similar to those in Room 13.

Room 45

South of the public rooms is a section of the building that is built on a lower level and served as storage and service areas, such as the 'Kitchen' 45. Halbherr *et al.* (1977:105-108) suggested that the room may have functioned as a kitchen but the cooking pottery that is expected to be found in such a room is missing. The south and north walls were dressed with pinkish gypsum dadoes (AT294-297 on the north and *AT*298-302 on the south) (Fig.5.299, Appendix 1: Drawing 49). Halbherr *et al.* (1977:105) refer to gypsum dadoes of the east and the west wall but I have not seen any traces of it on these walls. The floor was paved with irregular slabs of both gypsum and limestone, the majority being limestone. The treads of the staircase that led to corridor 44 to the south is made of limestone but there is a gypsum dado on the west parapet.

Light Well 46

The light well was paved with gypsum of which only a few slabs are preserved at the south–west corner. As usually the gypsum floor of the light well is bordered with limestone slabs on its east end where the open air space is. In the middle of the west wall there is a double door with gypsum doorjambs and thresholds that opens to Storeroom 16 where various bronze tools suitable for stone cutting were found (the large bronze saws, hammers and chisels) (Halbherr *et al.* 1977:108-109, Shaw 1973: 44-75). The thresholds and the floor slabs are all covered with soil and are not visible at the present. However they have been marked on the plan since they are mentioned in the publication and are drawn in the plan. On the south wall there are another two doors with gypsum doorjamb bases of which the easternmost (*AT*288-290) leads to Room 15 (interpreted as pantry) and the western leads to Room 45 (*AT*291-293).

Staircase 47

At the east end of the Light Well 46 is Staircase 47, with fourteen gypsum treads (Fig.5.300). At the top of the staircase there is a doorway towards Magazine 48 with gypsum doorjambs and threshold. At the west end of the north wall of the staircase there is a gypsum pier block that supported a wooden pillar.

North Magazines

This is the main storage area of the building and most storerooms are destroyed, not only due to fire but also due to the construction of the Mycenaean Megaron above them. Gypsum is only found in the four central storerooms (17, 61, 8, and 59) and the staircase that connects them (60) and magazine 18 (Fig.301, Appendix 1: Plan 19). Except for Storeroom 59 the rest of them are interpreted by the excavator as magazines for storage of liquid products such as oil and wine with common characteristic being a raised row of floor slabs in the centre as has been seen in Magazine 33 at Phaistos, and the existence of stools in some of them, noted by Stefani (Halbherr *et al.* 1951:121-122). I would like to add here that another common feature in magazines 17, 8, 59 of Agia Triada and 33 of Phaistos is the dark staining of the gypsum slabs that has also been seen in various magazines at Knossos and that is definitely indicative of oil storage.

Room 17

This is an exceptional room with ashlar limestone masonry, gypsum floor pavement and a central limestone pillar (Fig.5.302). The south-west part of the floor has been destroyed due to the construction of the 'Mycenaean Megaron' above. The floor slabs (*AT*304-328) form three concentric rectangular panels with the pillar at their centre. The outer panel is preserved only at the north east sides of the room while the middle panel (*AT*303, 313-315,319-123) is raised about 5-7cm above the level or the rest of the floor (Appendix 1: Drawing 49).

Although a possible ritual function of the room has been considered, due to its similarity with the Pillar Crypts of Knossos, no ritual objects were found and thus Halbherr *et al.* have concluded that the room probably functioned as storage area for liquids, based on the architectural characteristics that resemble features that occur in other storerooms of the same building, namely 8 and 18 with similarly raised floor slabs. It seems that gypsum is used only in the storerooms for liquid products such as oil and wine (Halbherr *et al.* 1977:122). The slabs of the floor are all heavily burnt and totally stained black. The black stain extends throughout the entire section of the slabs as observed in cracked and broken areas (Fig.5.303).

As already mentioned in the descriptions of Knossos black staining is usually associated with rooms that contained oil or spaces with poor ventilation such as corridors. Although the room was found empty without the expected pithoi that would confirm the above hypothesis, it is almost certain that the main content of this store room was oil which explains the severe conflagration and the black staining of the gypsum slabs.

Staircase 60

A door on the east wall of Room 17 opens to the Corridor and Staircase 60 that communicate with Room 59 to the north and 61 and 8 to the south. The staircase consists of eight gypsum treads (*AT*333-340) that are all burnt and totally stained black in a way similar to the slabs of storeroom 17 (Fig.5.304). At the top of the staircase a paved corridor continues to Room 61. The slabs that are in front of the entrance of Room 17 and close to the staircase (*AT*320-332) are found in a condition similar to that of the treads while the last two at the south end of the corridor are mostly missing.

Room 61

Room 61 is another storeroom for liquids, as suggested by the clay container that was placed under the ground with its rim at the floor level presumably set there to collect excess liquid (Fig.5.305). The floor is paved with gypsum slabs of which very few remains are preserved at the present but enough to demonstrate that the conditions during conflagration in the room were different from those in the adjacent storerooms which implies that the products that were stored here were different. The gypsum remains of this floor may have been burnt but they have not been stained black although the colours may have been slightly enhanced by fire (Fig.5.306).

Room 8

Room 8 is also a store room that is entered from Staircase 61. The walls are dressed with low (48-54cm) gypsum dadoes (*AT*348-362), which resemble the dadoes of Magazine 33 of Phaistos (Fig.5.307, Appendix 1: Drawing 50). The dadoes are set against the wall at a slight angle, the top leaning more towards the wall. They are burnt and stained black apart from small areas. On the floor lay eight round gypsum discs (or bases) with a diameter of 45-46cm and a groove curved around the edges (*AT*344-249).

Like the dadoes, they are burnt and stained and only five of them preserve original material while the rest are totally reconstructed. The discs have been interpreted as bases of containers for oil storage (Halbherr *et al.* 1977:127-129). There is only one floor slab preserved that is also similarly burnt and stained (*AT*343) (Fig.5.308). Finally the threshold (*AT*341-342) of the entrance, as well as the floor, was paved with gypsum.

Room 59

Room 59 has also been interpreted as a storeroom. There is part of a bench along the north wall that continued along the east wall as well but is mostly destroyed (Fig.5.309, Appendix 1: Drawing 51). Few fragments of gypsum slabs are still preserved in the rubble structure that formed the core of the bench. The clay mortar that was used for the attachment of the slabs on the bench is also preserved on the front of the north bench. The room was originally paved with gypsum slabs of which very few remains are preserved and show traces of severe conflagration, as seen in the above described magazines. A small three-step staircase at the south-east corner led to Storeroom 5 and a second at the north-west corner led to Storeroom 58. Both staircases are made of gypsum that exhibits the same fire marks.

Room 18

The floor of Storeroom 18, although mostly destroyed, is described by Halbherr *et al.* (1977:140-141). It is paved with gypsum slabs which form at the centre of the room an east-west oriented platform that is 7cm higher than the level of the floor. The gypsum slabs of the floor are not visible at present and have not been recorded and registered in my catalogue although they are colour marked on the site plan.

East Quarter (Quartiere Signorile Orientale)

The North East Quarter comprises of a complex of rooms that are characterised by their elaborate structure and the extended use of decorative stone (Fig.5.277 and Appendix 1: Plan 20). It includes some of the most typical palatial architectural features, such as halls with porticoes and light wells divided by polythyra (1, 21, 73) and stone lined interiors (gypsum benches, staircases, floor pavements and wall dadoes) (Fig.5.310). A distinctive feature of this complex is that the rooms as well as the fittings are small, which is the reason that led the excavators to name it 'Women's Quarter or Megaron' ('quartiere (o megaron) delle donne') (Halbher et. al. 1977:143). There was a second storey that could be reached by Staircase 75.

The south-west corner of the quarter has been destroyed due to the construction of the Mycenaean building above. Nonetheless, this area is protected from the rain water by a light shelter and therefore the gypsum remains are preserved in a relatively good condition. However, the slabs of the floor pavement of the rooms are not preserved apart from few slabs and thresholds in Rooms 68-72 (AT380-384, 399-402, 405).

Rooms 73, 73a and 20

Room 73 has a door on the west that opens to Room 68 and a two-door *polythyron* on the east that opens to Room 73a and a partially preserved five-door *polythyron* on the south that opens to Hall 21 (Fig.5.310). Room 73a is a small room that communicates with Room 20 (on the east) through a two door *polythyron* with gypsum doorjamb bases as well. The doorjamb bases are all made of gypsum as presumably are the thresholds although only one of them is preserved on the doorway to Room 68 (AT 382). The excavator refers to evidence of a gypsum floor pavement of somehow irregular slabs in 73 and in 20, but no traces of it are visible at the present (Halbherr *et al.* 1951:146).

Hall and Portico 21, Light Well 22

The hall has a door on the west that opens to corridor 71 and three polythyra: a five-door on the north, a three door on the east and another five-door on the south that connected it with Room 73, Portico 21 and Hall 1 respectively (Fig.5.310). The south *polythyron* is blocked by a later wall but the doorjambs are still visible at its base. They are all made of gypsum and probably so were the thresholds, although these are not preserved. A gypsum floor slab is preserved in the south-west corner of the hall (*AT*394) and the excavator refers to a second one that is preserved in the south-west corner of the portico but is not visible today (Halbherr *et al.* 1951:147).

Hall, Portico and Light Well 1

The hall has a door on the west that opens to Corridor 71 and a three door *polythyron* that connects it with the portico on the east and a door that opens to Room 2 on the south (Fig.5.311). Only one gypsum threshold is preserved at the west door (*AT*402). (Appendix:2, Plan 20). The north wall of the hall that was built in a later phase and blocked the north *polythyron,* as explained before, is veneered with gypsum dadoes (*AT*413-418) (Fig.5.312). The preserved parts of the west and east wall are also veneered with gypsum (*AT*412-415, Appendix 1: Drawing 52). The floor of the hall was paved with gypsum, as evidenced by the large rectangular slab (*AT*405), which is visible in front of the doorway to the corridor. Halbherr *et al.* (1951:149) mention that the slabs of the pavement of the hall form a large rectangular panel in the middle that is outlined by red painted plaster and that the pavement of the portico is made of large rectangular slabs of gypsum that are set transversally and are outlined by red painted plaster. The slabs of these pavements are also shown in the general plan of the site in the final publication (Fig.5.277). The floors are today entirely covered with soil apart from the aforementioned slab.

In the portico there are two gypsum benches built across each other along the north and the south walls, similar to those described in Room 4 (Fig.5.313, Appendix 1: Drawing 52). Halbherr *et al.* (1951:149) refer to the alternating *metope* and *triglyph* decoration of the front of the benches which, as in Room 4, I could not identify as such. In fact after closer examination of these benches I am convinced that there is no *triglyph* decoration here and that in most cases the projecting parts are flat pilasters or piers like those of the corners. In between the piers there is a rubble structure that is faced with a gypsum slab or *metope*. This is evident at the base of the south bench where the missing parts of the *metope* have not been filled with modern restoration mortar and therefore the interior of the structure is visible (Fig.5.314).

Room 2

Room 2 is a small elongated room that communicates with the halls through a door at its north-west corner and gives access to the landing of staircase 75 though a three step staircase (1m wide) at its south-east corner (*AT*461-463, Appendix 1: Drawing 53). Two large gypsum piers are placed laterally at the staircase (*AT*460 and 464, 0.82x0.70x0.71m) (Fig.3.415). The south wall is veneered with gypsum dadoes and a bench that runs along its entire length (Fig.5.316). A second gypsum bench runs along the east wall, while on the north wall is preserved a wall dado next to the door (Fig.5.317). The benches are the same as those in Portico 1 but of different lengths. According to the plan in the final publication the floor seems to be paved with four rectangular slabs that are not mentioned in the text and cannot be seen on the site at the present.

Staircase and Room 75

The staircase is the largest in the whole villa (1.88 wide) and consists of ten gypsum treads (*AT*491-500) (Fig.5.318). It has a common pier (*AT*460) with the small (1m wide) three step staircase, which lands in Room 2 and which can be considered as the first flight of the same staircase, and a second pier (*AT*490) of the same size on the other side (south parapet). The landing in between the two flights forms a small room with a gypsum pavement and benches along the east and the south walls (Fig.5.319, Appendix 1: Drawing 54). As in the previous rooms the floor slabs are not visible but are described by the excavators and are shown in the general plan of the site, forming parallel rectangular panels (Plan 4.4) (Halbherr *et al.* 1951:152).

Corridor 71

The corridor is paved with rectangular gypsum slabs two of which are visible and consist of colourful laminated gypsum in orange–brown hues (*AT*400-401). The rest of the floor slabs are shown in the plan but are mostly covered with soil and only parts of them are visible along the entire length of the corridor. The doorjamb bases and the thresholds of the doors that open into the corridor all consist of the same variety of gypsum as well (Fig.5.320).

Room 68 (Latrine)

Room 68, which has been interpreted by Halbherr *et al.* (1977:156-157) as a latrine, was paved with irregular gypsum slabs outlined by red painted plaster of which quite a few remains are preserved (*AT*384, 389) (Fig.5.320).

Magazines 69, 70, 72

These small magazines that are annexed immediately to the west of the halls and the staircase are also paved with irregular gypsum slabs. They are partially destroyed by overlying Mycenaean structures.

5.5 The Pyrgos Country House

The archaeological site known as Myrtos-Pyrgos, occupies a hill next to the mouth of the river Myrtos, overlooking the Myrtos valley and the Libyan Sea. The site is also situated next to the large Neogene outcrops of gypsum on the south coast of east Crete and not surprisingly presents the only example, in this part of the island, where gypsum has been employed to a substantial extent in architecture (Fig.5.321). The rather exceptional LMI building that dominates the top of the hill has been characterised by the excavator as a 'country house' rather than a villa, a term that he considers as more suited for grand houses in the country (Fig.5.323-5.324). The dominant location and the imposing architecture of the house indicate the high social rank of the residents. The archaeological evidence indicates the double character of the building as a local administrative and religious centre (Cadogan 1997).

The house shows characteristics of elite Neopalatial architecture. It was probably built in three storeys, the ground floor of which included a light well with gypsum bench, a gypsum staircase, veranda with a central pillar and two columns, storerooms and almost certainly a shrine on the first floor (Cadogan 1971, 1978). Gypsum was used here mainly for ashlar blocks, floor slabs, doorjamb bases, staircase treads, bench slabs and wall dadoes. The principal variety of gypsum that was used here is banded selenite with an average crystal size of 0.5 cm. Most of it has been affected by fire, as evident by the loss of translucency and the black staining in places (Fig.5.325).

The main facade of the house faces to the south and is made of gypsum ashlar masonry. Although the excavator refers to four courses of ashlar (Cadogan 1970), only two are preserved at the present (*MY*521-526) and a block above them that may be part of a third course (Appendix 1: Drawing 56). The blocks are 0.33-0.35m high and their width varies from 0.60-0.80m (Fig.5.326). Cadogan (1978) infers that much of the ashlar of the building and its annexes was 'robbed' in Hellenistic times.

In front of the façade is a veranda paved with gypsum slabs bordered by contrasting purple limestone pebbles. A raised walkway of flagstones separates the veranda from the paved courtyard in front of it that was probably the main square of the village (Cadogan 1971, 1976).

A **passage (1)** on the west end of the south facade leads to a **light well (3)** and a **staircase (2)** that are some of the most fine and best preserved parts of the house. The light well is paved with the same purple limestone pebbles while the north and the east wall are built with both sandstone and gypsum ashlar blocks (Fig.5.327). Four courses of ashlar are preserved of which the two lower ones are made of sandstone and the upper ones of gypsum (*MY*496-501, Appendix 2: Drawing 57).

It is quite interesting here that the upper courses of the north wall combine both kinds of blocks and despite the evidently wise choice and placement of stone in most Minoan building projects, I have not been able to justify this specific arrangement. The third course of the east wall is entirely made of gypsum blocks while the fourth is only partly preserved with only one block that is securely in the original place (*MY*501) and another five (*MY*502-506) that seem have been placed on the wall after excavation (Fig.5.328). At the west and of the north wall there is a door that opens to a pantry (11) and next to it, a gypsum wall dado (*MY*495). Next to the dado is a partly preserved gypsum door frame (*MY*492-494) that is quite a rare feature in Minoan architecture (Fig.5.329).

Next to the light-well (on the south) is a gypsum staircase that has been covered by the excavator with soil and stones in order to protect it from direct effects of rain water. In his report he describes the staircase as follows "a very well preserved staircase, built in an identical way to the Grand Staircase at Knossos, it is walled on one side, but has an open parapet that descends in steps on the other. On the parapet at each level were charred remains of a wooden column *in situ*. There are nine ashlar steps, each in 0.18cm in height. The wall on the south side may have had a gypsum dado at its base and have been plastered above" (Cadogan 1971:506). I was not able not see any detail of the staircase in the photos that were published by Cadogan in the *Archaeological Reports* (Cadogan 1978, Fig.23 and 25) it seems that the coping of the parapet was also made of gypsum (confirmed by Cadogan, personal communication 2000) (Fig. 5.330)

Opposite the light-well there is a gypsum bench with alternating *metopes* and panels with *triglyph* decoration (3 *triglyph* panels and 2 *metopes*) and gypsum back and side panels (*MY*513-518) (Fig.5.331-5.332 and Appendix 1: Drawing 58). Soon after its discovery it was covered with soil and stones like the staircase. It seems that this temporary protective measure was quite effective in preventing the dissolution of the gypsum surface given that this bench, as far as I can see, is the best preserved that has been recorded in the course of this study. The *triglyph* decoration is carved only in the middle of the panels and differ from those of Phaistos where the carving is continuous along the entire length of the panel. Perhaps the term *triglyph* is more suited for the bench of Myrtos than the benches of Phaistos and Agia Triada where most of the projecting panels are either flat pilasters (all benches in Agia Triada and in Room 50, Room 70, Stoa 65 and perhaps Room 24 in Phaistos) or carved with continual grooves.

The excavator has suggested that there was a wooden floor in front of the bench and along the passage (1) based on the charcoal rich layer found on the bedrock. Several gypsum slabs were found in the passage fallen from the upper floor where according to Cadogan (1992), there was a shrine that exhibits close links to the Knossian cult practices.

On the west side of the courtyard is another building (13-14) of which the veranda was paved with gypsum. The architecture of the building is comparable with that of the country house and to the same high standards. The excavator suggests that it may have been a pavilion or a shrine although it lacks ritual contents (Cadogan 1978, 1997). Apart from the partly preserved slabs of veranda there is no other gypsum in this area, at least not *in situ*.

However, the majority of the architectural gypsum is not in found *in situ* and therefore it is impossible to trace its original location in the building. Fortunately it has all been collected by the excavator, in two piles next to the site, and most significant pieces have been catalogued and sketched. Thus, I was able to make some observations as regards the variety that was used, the function and the cutting and shaping tools and techniques.

The amount and the shapes of the loose fragments that were found during the excavation indicates the extended use of gypsum in the upper storey/storeys floor for floor pavements, wall veneering, staircases, doorjamb bases and perhaps some ashlar walls with small rectangular blocks (Fig.5.333). Red painted strips of plaster (3-3,7cm wide and 1.5cm thick) that were found in passage (1) were most likely framing the gypsum floor slabs as practiced in the buildings of Messara and Knossos.

The use of a relatively large volume of gypsum for ashlar blocks is obviously owing to the abundance of gypsum on the neighbouring hills just a few hundred meters away from the site. The blocks vary in width from 40-60 cm and in height from 25-45cm, somewhat smaller than those of the light-well, and have finished front and side surfaces while the back is roughly hewn reminding the large orthostates of Knossos even though they are much smaller (Appendix 2: Drawing 60).

The sides of the loose slabs (Fig.5.334) as well as the side panel of the bench (Fig.5.335) are bevelled, presumably for better attachment on the wall. This is the only case where such a practice has been attested but we should bear in mind that the edges of the slabs are usually sealed with modern mortar and therefore such details are hidden. Megaron Nirou is the only other building where several slabs with finished edges were loose and available for study. However, none of the slabs there had bevelled edges or any work marks at the back surfaces. The raw material selection process at Pyrgos, appear to be quite advanced, since the chosen variety of gypsum, when compared with the ones found at any of the other sites, seems to resist weathering to a greater extent. The quality of carving and finishing of the stone bears all the hallmarks of highly skilled masons. Flat and pointed chisels as well as saw marks were identified on the back and the sides of slabs.

The use of gypsum at Myrtos may indicate some Knossian influence, but at the same time the stylistic and technological characteristics distinguish Myrtos clearly from the sites of Central Crete. The trend may have been imported from Knossos but has been adapted to the local style and practices. We cannot exclude however the hypothesis that the travelling mason's arrived at the site in order to execute the quarrying, cutting and shaping of the stone, techniques that were not practiced by the local people until LMI, when the house was constructed, since there is no evidence for the use of worked stone in the preceding periods.

CHAPTER 6

DISTRIBUTION AND CONSUMPTION OF MINOAN GYPSUM

In this chapter I will discuss the distribution of Minoan architectural gypsum on the island including six more sites where gypsum is found in small quantities, some of it not in context. I will then focus again at the five major 'gypsum sites' and will examine the consumption of gypsum and its impact on palatial architectural design by means of volume and surface estimations. Finally, I will briefly review the sites with architectural gypsum at the Cyclades and mainland Greece.

6.1 Sites with small volume of gypsum

6.1.1 Archanes

Gypsum is found in the Late Minoan building at Tourkogeitonia, but not in a quantity comparable with the above sites, despite the numerous occurrences of gypsum in a distance of 4-5km. It should be mentioned, however, that this picture may change as the archaeological research at Archanes is still in progress. The architectural gypsum that has been uncovered up to now suggests that gypsum must have been used to a quite large extent. Gypsum doorjamb bases are found at the *polythyron* in Area 3, benches dressed with gypsum slabs were built along the west wall of Room 4, the south wall of Room 25, and the west north and east walls of Hall 10. Sakellarakis also mentions that gypsum blocks found in the destruction layers in Stoa 7 "have been pulverised so completely" that the identification of individual structural elements is difficult (Sakellarakis 1991:30, 32, 36, 38). Most of the above structures have been temporarily covered with soil and therefore it is not possible to have an idea of the varieties that are used. The few visible gypsum elements are large gypsum doorjamb bases that are affected by fire and most likely consist of nodular and lenticular selenite.

The recent excavations at Archanes have brought to light more structural gypsum used in storage areas that has not been published yet. The study of the architectural gypsum from Archanes should be the next step of this work and will probably add quite interesting information as regards the relations of Archanes with Knossos and the possible access to the Knossian sources of gypsum.

6.1.2 Galatas

The recently excavated palace of Galatas is the dominant palatial centre of the fertile land of the Pediada, a region which, as indicated by the extensive survey by Panagiotakis (2004) and the excavations by Rethemniotakis (2002, 2004), has close links with Knossos and shared the same social, cultural and political ideas.

The palace was built during the transitional period MMIIIB/LMIA and shows close Knossian contacts as demonstrated by pottery, wall painting fragments, and the architecture. The excavator notes that Galatas "must have incorporated essential architectural and functional features from the early Neopalatial (MMIII) Knossian Palace" (Rethemniotakis 2002:58).

Amongst the Knossian features that have been attested on the site are the gypsum doorjamb bases and a couple of pillar bases that are exclusively used in the North Wing of the building. This wing is the largest one and probably functioned as the residential and official quarter of the palace. It is an elaborate construction using sophisticated building methods and refined materials (Rethemniotakis 1993, 1994, 2002). The variety of gypsum that is used here is massive selenite with well oriented crystals with an average size of 2-3cm, identical to the variety that is available at the nearby outcrop of Myrtia, about 13km north of the palace, which is the most likely source of its provenance. Since the Myrtia outcrop was only recently noticed by Rethemniotakis and Warren, they both assumed the Knossian origin of the Galatas gypsum in their earlier publications (Rethemniotakis 2002:60, Warren 2002:204).

The building was abandoned within the same period when LMIA pottery was still in use, and before its destruction. Under these circumstances it is not surprising that all the doorjamb bases are unaffected by fire, as the destruction of an empty and abandoned building is not expected to be followed by fire.

6.1.3 Pseira

In the LMI town of Pseira there is a complete doorjamb base in secondary use, found in the south-west corner of House AQ. It was first noticed by Geyla Wang in 2000 during the cleaning of the site by Betancourt and his colleagues and it is therefore not mentioned in the final Pseira publication that was already in press. According to Betancourt the doorjamb base was reused in an LMIB context but originally was probably part of an LMIA structure (Betancourt 2000 pers. comm.).

The Pseira harbour has probably served as a stopping point on the Knossian trade routes with the East from the LMIA period when Knossian influence begins in the pottery styles, the wall paintings and the architecture. The Knossian influence increases gradually and during LMIB Pseira seems to share the same religious beliefs. New concepts are adopted in architecture such as the *polythyron* or pier-and-door partition but executed with local materials such as sandstone from the Mochlos quarry that has also been used at the Palace of Gournia and the 'Megaron' of Mochlos (Soles 1983, Betancourt 998:118-119, 2002, 2004)

Considering the Knossian influence in all aspects of life in LMIA-LMIB Pseira the presence of gypsum doorjamb needs no further explanation. The gypsum doorjamb of Pseira is the usual L-shaped one that alone cannot indicate the existence of a *polythyron* and is quite small (42cm length x 15 height x 21 width) but perhaps one of the most significant gypsum architectural members of Minoan Crete. The reason which makes it so important is that although the site is located on a little island exactly opposite Altsi, the largest outcrop of Permian gypsum on Crete, it is macroscopically apparent (confirmed by petrographic analysis, see Chapter 3) that the doorjamb base is made of unaltered (unaffected by fire) nodular and lenticular gypsum (Fig.6.1-6.2)

As shown in Chapter 3, this variety occurs only in the Neogene outcrops of the Knossos area and to a less extent and at Myrtos on the south coast. However, this variety is not used at Myrtos at all neither exists in exploitable form and extent, thus, the rock was most likely imported from Knossos, but there is no evidence to verify whether it arrived as raw material, as a rough block that was then worked on site or as a shaped and finished fitting. It is even more interesting that no gypsum has been found in the neighboring palace of Gournia neither at Mochlos which is only a 5km away from Pseira.

Apart from gypsum, other stones were brought to the island for special architectural features such as sandstone from the quarry of Mochlos for pillar, pier and jamb bases. A red stone column base and a slab of white siliceous limestone are two more examples of stone that was imported for building purposes (McEnroe 2001:30-31).

6.1.4 Palaikastro

Bosanquet (1902) notes a scrap of gypsum wall revetment that was found in House A at Palaikastro, which he considers as an interesting proof of Knossian influence, since gypsum "is not readily obtained at Palaikastro, the nearest deposits being near Roukaka" (Bosanquet 1902:306). It seems that Bosanquet was not aware of the neighbouring but not used Permian outcrop of gypsum at Kavo Sidero, only a few km away from the site.

I have not seen the wall revetment fragment that Bosanquet mentioned and I cannot be certain of its function, as he does not make clear the criteria upon which he identifies the gypsum fragment as part of wall revetment. However, more fragments of gypsum have been found in the recent excavations of the British School at Athens, most of which are fallen from the upper storey and appear to be parts of doorjambs (MacGillivray and Driessen 1998 pers comm.).

The petrographic study of two gypsum samples from the recent excavations indicates that the most probable source of provenance is the Neogene outcrops of central Crete. Both samples show dehydration features and have derived from dehydration/re-hydration of nodular and lenticular gypsum that is commonly used at Knossos. The doorjamb base of Pseira is also made of the same variety as are possibly those of Zakros.

6.1.5 Zakros

At the palace of Zakros there are three gypsum blocks found in the north-east part of the building, one in Room XXXV, another one used as a corner pier in Room XXXVI, and the third at the south east corner of Room VI. A fourth block is found at the entrance of Room IX which Shaw (1973:23) described as 'rough doorjamb'. Another three doorjambs, partly preserved and heavily weathered, were brought to my attention by L. Platon in 1999. They were found in Room F, and are not *in situ* but they can be securely identified as L-shaped doorjamb bases due to the characteristic projections that are preserved. L. Platon has assumed that these are fallen from the upper floor (L. Platon 1999 pers comm.).

Shaw, based on the scarcity of gypsum at Zakros and in east Crete in general, suggested that "these small blocks may have been brought by ship perhaps as ballast, and then left at Zakro when the ship was loading up with cargo" (Shaw 1973:23). His suggestion, however, refers only to the three small blocks (approximately 0.30x0.38x0.38m) that he was aware of, in Rooms XXXV, XXXVI and IX. The block that is found at the south-west corner of Room VI is quite a lot larger (0.43x1.05x0.72cm), while the doorjamb bases, because of their specific function, cannot be interpreted as ballast.

The gypsum of Zakros macroscopically resembles white alabastrine gypsum but the petrographic study showed dehydration features that were caused by fire and the former rocks are most likely the primary Neogene varieties, selenite and nodular and lenticular rock. It seems therefore very possible that it was brought from the outcrops of the Knossos area.

The palace of Zakros was built at the end of the LMIA period after a severe destruction in a completely new layout. Strong Knossian influence is evident in the architecture of the new monumental palace which marks major political and social changes. The attempts of the new ruling class to impress and to stabilise its power is reflected in all aspects of material culture (Platon 2004). Within this context of grand architecture, gypsum, the prestige symbol of the Knossian palace and its dependencies could not be dismissed. Despite the distance from the sources, a small amount of gypsum was shipped over and installed in the building. Again, we cannot be certain whether it was brought as raw material or in finished architectural members but nevertheless its presence definitely strengthens the idea of the Knossian political control over Zakros at the end of the LM IA period and the suggestion of L. Platon (2002, 2004), Warren (2004) and Weiner (1990) that Zakros was the eastern port of Knossos.

6.1.6 Amnissos

At Amnissos there are doorjamb bases and small blocks of gypsum that are still visible within the villa excavated by Marinatos, and there was a little used within the nearby houses excavated by Alexiou (Marinatos 1933). In the west protective/retaining wall there are 18 ashlar blocks of which one (No 9) is made of gypsum and the rest of sandstone. Sturmer (1992:140) notes that these blocks are not shown on the retaining wall at the photos that were published by Marinatos (1932) and assumes that they were probably placed there in 1947 by N. Platon. He identified the gypsum block at the excavation photos fallen in between the west facade and the west retaining wall (Sturmer 1992:135, 140, Table 21.6).

The gypsum ashlar is similar to that of Knossos, with even front and side surfaces and irregular back, but in a smaller size (80cm length x 28cm width x 36cm height). It consists of massive selenite that has been affected by fire and is completely white. The average size of the former crystals is 1cm. This variety is quite common in central Crete and has most likely been obtained from one of the outcrops near Knossos.

Marinatos also mentions two poorly preserved pier blocks, south of the north wall of the megaron which I was not able to find on the site (Marinatos 1932:79, 1939:443). Gypsum ashlar blocks (square and rectangular) were also found in Area F (Rooms B8 and H2) and were considered by Sturmer characteristic of the new palace period, found here in a later context (Sturmer 1992:194,197, Plate 131, 55.3). Finally, north-east of Corridor 4 there are three heavily weathered gypsum doorjamb bases (Sturmer 1992: Table 16.4).

The gypsum of Amnissos is quite weathered and was only macroscopically examined. Both varieties of central Crete, selenite and nodular and lenticular gypsum are represented in the building and all the rocks are completely burnt. The gypsum, has obviously been brought from the Knossos outcrops and was probably transported through a Minoan road system that was established in order to facilitate the communication of Knossos with Amnissos which most probably served as a harbour of Knossos and where the produce of the Pediada may have also arrived via a well established trade route (Hood 1981, Panagiotakis 2004).

6.1.7. Kommos

Finally, a single small slab of gypsum has been found at Kommos in a small room of which the function has not been identified yet. It was probably brought here from the neighbouring Agia Triada but its fragmentary state and the uncertain context in which it was found does not allow the suggestion of any possible function (Shaw, M. 1996 pers comm.).

6.2 Distribution of Minoan Gypsum

The survey of gypsum outcrops on Crete demonstrates that the material is relatively easy to access and to extract, with a variety of morphological characteristics per outcrop. Besides, there are quite a few sources near the coast and therefore the rock could be transported by boats. Despite the availability and the working qualities of gypsum as a building material, *in situ* analysis indicates a restricted pattern of Minoan gypsum usage.

Only five sites make use of the rock in significant quantities: Knossos, Phaistos, Agia Triada, Megaron Nirou, and Pyrgos (Fig.6.3) and possibly Archanes. The recently excavated site of Galatas has been now added to the sites that used gypsum, but again not in the same manner and extent as the above mentioned sites. Other Neopalatial sites, often coastal, such as Amnissos, Pseira, Palaikastro and Zakros and Kommos have only a few gypsum blocks, doorjambs, or indistinct fragments, that are usually considered by the excavators as evidence of Knossian influence (Fig.6.4). Architectural gypsum doe not appear at all in the west which is not surprising as Driessen (1991) has already demonstrated that the palatial architectural features are concentrated in the central and east Crete with highest frequency in the region of Knossos.

It is apparent so far, that exploitation of gypsum remains local, with main consumers the large palatial sites of Knossos and Phaistos, a couple of other 'elite' buildings, Agia Triada and Megaron Nirou, that are culturally and politically related to them, and Pyrgos that although the furthest site with no apparent geographical relation to the others, shares quite a few common architectural features with the palatial centres.

All the sites, with the exception of Megaron Nirou, have potential quarries within a distance of a couple of kilometres. A longer distance, of at least 12-13 km by land routes, was required for the transportation of the stone to Megaron Nirou, from the closest source that is the outcrop of Gypsades hill near Knossos. It is significant however, that major sites such as Mallia, Chania, Gournia, Petras, Mochlos, Tylissos, Vathypetro, make no usage of gypsum, although some of them could have easy access to the Permian sources of the east and west Crete.

Mochlos for example, had near at hand (only a couple of kilometres away) one of the largest outcrops of the island, at Altsi, with some of the most attractive varieties of white fine-grained (alabastrine) gypsum, often banded with grey veins (Chapter 3, Fig. 3.1-3.2). It is quite surprising that there is not even one single piece of this material used in the buildings excavated so far. They instead exploited instead the sandstone quarry that was closer to the site, just opposite on the coast (Soles 1993).

Gypsum is also absent from the neighbouring site of Gournia, 15 km further to the west. Soles (1983) has demonstrated that the ashlar that was used in the remodelling of the Gournia palace (in LMI), came from the sandstone quarry of Mochlos, which the Gournia settlers utilised in order to produce cut blocks for ashlar masonry with an attempt to resemble the great palaces of Knossos, Mallia and Zakros.

Considering that most of the year the area suffers strong north winds the journey to Mochlos would have required quite a good planning. One should then wonder why they did not use any of the gypsum of Altsi, which is a little closer than the sandstone quarry of Mochlos, which would have definitely looked more attractive according to the Knossian aesthetics.

It is possible that the eroded surface of the outcrop did not make it a promising (admirable) source for exploitation. The cracking of the Permian gypsum, a result of the expansion associated with the conversion of anhydrite to gypsum, may have discouraged the Minoan masons. Moreover the dissolution patterns that are more intense on the surface of the fine grained Permian gypsum than on the selenites of the Neogene outcrops may have also have contributed to the neglect of the source, though it could have been used only for the decoration of interiors, which has been the main function of fine grained gypsum at most other sites. The same intense dissolution patterns are observed on the fine grained laminated gypsum of the Messara outcrops but did not prevent its lavish use at the palace of Phaistos and Agia Triada. Besides, if the durability of the stone were more important than its aesthetics or its symbolic character the ultimate choice would have been the limestone, which can be found in the immediate vicinity of the site and not sandstone from a further distance.

Given the technology and the bronze tools that were available to Minoan mason's of Mochlos and Gournia, it seems that it would not be difficult for them to find a suitable bed at Altsi outcrop for the extraction of architectural gypsum. Large boulders of the stone, already loosened due to the cracking of the upper beds, could be utilised for this purpose without the need for quarrying.

Altogether, it does not seem to me that any natural barriers made the Altsi outcrop inaccessible to Mochlos or Gournia settlers. It is more likely that Mochlos and Gournia did not follow the Knossian fashion of gypsum interior decorations despite the similarities in the architectural features and functions of Gournia and Knossos (Soles 2002). It is also significant that the Knossian ceramic imports that are a common feature at Pseira are not as common at Mochlos or Gournia (Betancourt 2004).

It is apparent that although the basic design and organisation of the palatial buildings of Neopalatial Crete follow the Knossian prototype or, as Weiner (1990:144) phrases it, display the architectural innovations of the Neopalatial 'School of Knossos', it seems that the Knossian style was not fully adopted by all other settlements or in all aspects of material culture.

For example, the sandstone facades of Mochlos and Gournia find their closest parallels at the palaces of Zakros and Mallia, which invites more research on the significance of the use of sandstone and other stones in Minoan architecture. Similarly, at the palace of Petras further to the east, gypsum is not used in architecture, although it could be obtained either from Altsi or from Cavo Sidero at a distance of nearly 20km each. The sources are not that close but the rock could be transferred by boat and it would not require much more effort than that required for the transfer of gypsum from Knossos to Megaron Nirou. Moreover, if its extensive use was difficult and costly operation, such sites could at least have acquired a few doorjambs or blocks as the palace of Zakros. The complete absence of gypsum from the site is in a good agreement with Tsipopoulou's (2002) suggestion, based on the study of the artefacts, that while Zakros was under the control of the Knossian state at the end of the LMIA period, Petras remained an independent administrating centre which controlled its pre-existing hinterlands.

At Palaikastro, Driessen (1999) has interpreted the presence of the LMIA hall as an indication of some sort of Knossian influence or presence and conjectures that the hall was part of the residence of a Knossian settler or of a local that that introduced non-local architectural features and enjoyed wealth and luxury as implied by the use of several unusual and probably valued stones, such as serpentinite, red and green schist and grey/green *cape sidero* limestone, but not gypsum. He further suggests that the intentional dismantling of the hall at the end of the same period may have been a symbolic action of revolt and demonstration of the local independence. If Driessen's hypothesis is correct, then gypsum, the most distinctive prestige symbol of the Knossian elite architecture, would be the first architectural feature to be demolished and perhaps this can explain its absence from the remains of the Hall as well as the fragmentary state of the architectural gypsum of Palaikastro in general.

It seems so far that architectural gypsum from the Knossos quarries travelled to Amnissos, Megaron Nirou, Pseira, Zakros and Palaikastro and perhaps Archanes, while Phaistos, Agia Triada and Pyrgos and Galatas exploited local sources (Fig.6.5). The restricted distribution of architectural gypsum in the New Palace period indicates that utilisation is the result of conscious choice at specific sites that established close social and political links with Knossos or were under the complete political control of the Knossian state or within the economic territory and the cultural boundaries of Knossos as determined by Warren (2004). Within these sites, the material is concentrated in elite buildings. Even at Knossos, where the Gypsades quarries might be expected to be of open access, gypsum is found only in the Palace, the Little Palace and the most outstanding neighbouring houses such as the S. House, the South East House, the Royal Villa, the House of the Frescos, and the House of the Chancel Screen and at non-residential structures such as the Caravanserai the Temple Tomb and Tomb 1 at Isopata. Judging from the few town houses that have been excavated at the palace sites, only small quantities are found in vernacular architecture of the LMIII/LMIA period and usually not in a clear architectural context. When focusing on individual buildings, gypsum is again found in the finest rooms, where specific varieties are clearly preferred for decorative purposes.

The examination of the Minoan gypsum has shown so far that circulation of the material is held within certain social levels. In a period in which prestige is manifested in all aspects of material culture, the decorative function of gypsum adds one more exclusive characteristic to Minoan architectural design, reflecting the changes in social organisation, the development of an elite class and most of all the expansion of the Knossian power at least in central and east Crete that has been long been argued by several scholars and most recently discussed by Warren (2002, 2004), Betancourt (2002), L. Platon (2002, 2004) and other scholars. It is clearly understood that gypsum decorations are indicators of the social rank of the building's residents and of the close cultural and political links with the palatial centre and the ruler or ruling class of Knossos. Therefore as a prestige symbol of the elite, gypsum had to be kept within the limits of palatial architecture and thus its exploitation and consumption had to be under control.

Further, the technical qualifications and the equipment that was needed for the extraction and the shaping of the stone were not readily available to all members of the society and the labour that was required for the movement of large bulks of stone could only be provided by the state.

Prestige symbols are culturally dependent, and therefore can be received as such only within the cultural context that makes use of them, and therefore absence of a certain prestige symbol from a site does not necessarily suggest a lower social level. It may indicate a different cultural context, which makes use of different symbols. This can explain to some extent the absence of gypsum from Mallia, Petras, Gournia, or Mochlos, as well as its presence at Amnissos, Megaron Nirou, Pyrgos, Zakros, Pseira and Palaikastro which are all sites that have provided evidence of Knossian influence in the both architecture and the crafts.

6.3 Patterns of consumption of Minoan Gypsum

The patterns of consumption of Minoan gypsum can be examined by means of calculation of the total volume used in the building projects and identification of the different varieties and their corresponding architectural functions. A piece-by-piece record of four thousand gypsum architectural members, from the major Minoan sites that utilised this stone reveals a striking range in the variety and function of gypsum between sites.

The palace of Knossos is the main consumer of gypsum with 408m^3 calculated on the 85% of the existing remains, followed by the palace of Phaistos with 47m^3, the villa of Agia Triada with 27m^3, the Pyrgos country house with 10m^3 and finally Megaron Nirou with 4,8m^3 (Fig.6.6).

Knossos uses gypsum for a great variety of functions of both structural and ornamental character. The majority of the volume that I have measured at Knossos, 62% of it, is consumed in the production of structural architectural members such, as ashlar blocks, orthostates, wall piers, pillar bases, staircase treads and jambs. Another 38% is used for lining or dressing rubble structures and is therefore considered here as ornamental although some of its functions, such as the cist lining, have more of a practical than a decorative character. Thus the functions that are included in the volume of ornamental gypsum are: wall dadoes, floor slabs, thresholds, coping of staircase balustrades, bench slabs and cist lining (Fig.6.7-6.8).

At Phaistos and Agia Triada, almost equal amounts of gypsum have been used for structural and ornamental functions (Fig.6.9-6.12). Gypsum is used here for all ornamental functions that we have seen at Knossos apart from ashlar, pillar blocks and orthostates. Also at Phaistos there is no cist lining but there is some in Agia Triada in the wall cists at the North-West Quarter (Hall 13 and Room 52).

Megaron Nirou has used the smallest quantity of gypsum but the great majority of it is found in a good context and allowed a detailed account of the different morphological varieties, and their use in architectural design (see Chapter 5). 93% of the material is found in situ in primary context and another 7% is found in loose slabs, fallen from the upper storey or from the upper parts of the walls of the basement. The great majority of gypsum here, 78% of the total measured volume, is used for ornamental functions including all those that we find at Knossos except for cist lining (Fig.6.13). The only structural functions of gypsum at Megaron Nirou are doorjamb bases, which constitute another 18% of the total measured volume, and staircase treads which represent the remaining 4%. In the volume of ornamental gypsum here are included the floor slabs, wall dadoes, thresholds, and bench slabs (Fig.6.14). The limited use of gypsum for structural elements is not surprising as this is the most distant site from the sources that uses gypsum in such an extent.

At Pyrgos the architectural context of the great majority of gypsum is uncertain. Most of the material is found loose but its architectural functions can still be recognised. As at Phaistos and Agia Triada an almost equal volume of gypsum is used for ornamental and structural functions (Fig.6.15). Ashlar blocks constitute 51% of the total estimated volume; loose slabs another 40% and only 9% is used for all other functions (Fig.6.16). The majority of ashlar blocks, 64% of the estimated volume of ashlar, are loose, 17% is in situ, 19% has been reused in later structures (Fig.6.17). The functions of the other 9% of the total volume, which is in situ include, wall dadoes, staircase treads, floor slabs, doorjamb bases, door frames and bench slabs (Fig.6.18). The minimum estimated volumes of gypsum that are consumed at each of the five building for each specific architectural function are plotted in (Fig.6.19). The disparity in the volume between Knossos and the other sites, can be partly attributed to its much larger size and partly to the extensive use of gypsum for large, architectural members such as ashlar blocks, orthostates, large jambs, wall piers and pillar blocks, which are absent from the other sites. Besides, a rather large amount of the gypsum is found at the West Magazines, where the main corridor, the magazines as well as the cists are almost entirely dressed with revetment slabs. Gypsum is also found at the magazines of Phaistos and Agia Triada but not to an extent comparable to that of the West Magazines.

All the above values refer to the minimum total volumes as measured at each of the buildings, and consequently the variations in the consumption of gypsum reflect to a certain extend the different size of the buildings. Therefore in order to have comparative data we need to look at the proportion of gypsum volumes per unit of built area. An estimation of the volume that is used per $100m^2$ of built area showed that once the size factor is withdrawn the pattern of consumption is quite different. Knossos still remains the main consumer but the second site is clearly Pyrgos, the only other site where gypsum ashlar occurs. Agia Triada comes third, then Megaron Nirou and finally Phaistos (Fig.6.20-6.21).

It is apparent the key factor governing the employment of gypsum for structural elements is local availability, which explains the low proportion of structural gypsum at Megaron Nirou. Further the absence of gypsum orthostates and ashlar masonry from Phaistos and Agia Triada despite the proximity of the outcrops be attributed to the particular characteristics of the fine grained balatino or laminated gypsum that did not make it suitable for outdoors use (i.e. the intense dissolution patterns of the surface). It is also possible that the balatino beds were not thick enough and not in sufficient quantities for the extraction of ashlar blocks with consistent crystallographic characteristics and therefore its structural function was limited to the few pillar blocks, piers, and large jambs that were used in the most outstanding parts of the buildings such as the magnificent entrance of the Phaistos palace. Levi was confronted with the same problem in his search for suitable and sufficient in size gypsum beds for the extraction of rock for the Phaistos restorations (see Chapter 3).

The volume of gypsum that has been consumed at each of the sites indicates the scale of the quarrying and building projects, as well as the required labour investment, but does not necessarily indicate the impact of gypsum in the architectural design of the examined buildings. A further estimation of the surface that gypsum would have initially covered per unit of built area allows the comparative study of the sites and reveals the significance of gypsum as an integral element of the architectural design of the examined buildings.

The calculations include both horizontal and vertical gypsum surfaces within the residential quarters of Knossos and Phaistos, the North-West Quarter of Agia Triada and the entire building of Megaron Nirou excluding the storage area. For the two palaces, I have estimated the total gypsum surface only for the residential areas that are the main sectors where gypsum was used, and where we can assume that most of the gypsum fittings were installed in one building phase. Such estimation was not possible for the site of Pyrgos since most of the material is loose, and we cannot be certain about its original disposition.

At the Domestic or Residential Quarter of Knossos an area of $512m^2$ is dressed with gypsum, while the gypsum surface that is displayed at the equivalent quarter of Phaistos and the North –West Quarter of Agia Triada is almost half of it. At Megaron Nirou the surface is much smaller, almost one quarter of the gypsum surface of the Knossian 'Domestic Quarter' (Fig.6.22).

The size of the buildings is again the main reason for the disparity of gypsum surface at Knossos and therefore a further estimation of the surface at the basis of the same scale was required in order to be able to compare the extent of the gypsum decorations in the buildings. If we look at the proportion of gypsum surface per 100 m^2 of built area there is some balance in the estimated values at all four sites. At the residential quarters of Knossos, 73m^2 of visible surface is faced with gypsum per 100m^2 of built area. The residential areas of Phaistos and of the North–West Quarter at Agia Triada follow, with almost equal surface of around 60m^2, and finally Megaron Nirou with 50m^2 (Fig.6.23-6.24).

It seems, therefore, that a rather large area of the visible surface in these buildings was dressed with gypsum and although large volumes are consumed for bulky structural elements the main function of gypsum in Neopalatial architecture is decorative. It was principally used as an ornamental stone, in the form of thin paving slabs and revetments, which were applied as facing to rubble structures. This very efficient method of creating a luxurious interior space with minimum consumption of valued materials appears for first time in the palaces of Crete and especially in the New Palace Period a consequence of the increasing demand for decorative stone that is associated with the expansion of the power of the Knossos state in central and east Crete. The emerging privileged ruling groups demanded outstanding structures and materials of social significance as status markers that projected their power.

The expression of power through monumental architecture that requires the use of exclusive materials, specialised skills and substantial labour is evident in many ancient cultures including the Mesopotamian and the Egyptian that are the closest to the Minoan culture in both chronological and geographical terms as well as in modern societies around the world. Wright (1987) interprets the exclusive use of conglomerate in the construction of the most outstanding monuments in Mycenae such as the Lion Gate and the tombs of Atreus and Klytemnestra and also in the construction of key monuments in the neighbouring Argos and Tyrins as a public symbolism that was established by the Rulers of Mycenae as part of a program of pronouncing the colonisation of their power over the general region of Argolid.

Trigger (1990) also emphasises that the need to express power through monumental architecture may be greater during the formative stages of early civilisations or at times that centralised power is increasing which is probably the reason for the use of gypsum at the first place in the earliest phase of the early palace of Knossos. Following that, the expansion of the Knossian power in the LMIA period resulted in the proliferation of the palatial architectural style as documented by Driessen (1990) and the establishment of the special character of gypsum as one the most characteristic and exclusive symbols of the Knossian elite.

6.4 Architectural gypsum in the mainland Greece and the Cyclades

Apart from Crete, gypsum has also been used on Mainland Greece and in the Cyclades. The most well known examples are the two fragmentary reliefs, possibly from the outside Facade of the Atreas tholos tomb at Mycenae, which are included in the 'Elgin Collection' of the British Museum. The remains of the first one were interpreted by Evans as parts of the head and the back of a "galloping bull with lowered head, including branches of an olive, rising behind the back of the bull", (Evans 1930:194-197, Fig.133, 135). The other fragment was interpreted as the front legs of a stationary bull (Evans 1930:198-199, Fig.136, 137).

Evans further notes that chemical analysis of the stone proved that it is identical to the gypsum rock that is largely used in the construction of the Minoan palace (Evans 1930:192), and discusses the remarkable similarity between the bull's head of the Mycenae relief with the painted stucco head from the Northern Entrance Passage of the Knossos. He concludes that the "relief fragments belong to two parallel compositions answering in their general character to those of the Vaphio cups and like them going back to the monumental prototypes of the Northern Entrance Porticoes of Knossos". He believes that gypsum was imported in Mycenae from Knossos as a roughly hewn raw material on which "the details and sculptural designs were carved later with convenient reference to local conditions" (Evans 1930:198, see also Evans 1935:228).

Further evidence of Knossian influence is presented by the gypsum columns of the 'Tomb of Klytemnestra' along with a carved fragment that was found nearby. It has been described by Wace as "a fragment of gypsum carved with spiral patterns with the angles filled with a plaited design", which probably came from the capitals of the columns placed on either side of the doorway (Wace 1921:359, Fig.77). Although Evans could not find this fragment in the Museum of Athens, he believed that it was a Cretan import, not only because of the material itself but also because the decoration is typical of that applied to earlier stone objects of the MM III period (Evans 1935:229).

Moreover, apart from the above mentioned fragments, gypsum is used for paving slabs at the citadel of Mycenae, the porch of the Megaron and the vestibule, as well as at the porch of Tiryns for dressing benches (Wace 1921:232, 238, 240, Mylonas 1957:56, 1966: 2-64, Gale *et al.* 1988:58). At Akrotiri on the island of Thera, gypsum floor slabs were found in the House of the Ladies and in the West House (Marinatos 1972:11-20, 1974:8-11, 19-23, Gale *et al.* 1988:58).

Examination of gypsum samples from Akrotiri, Mycenae, and Tiryns by Gale *et al.* (1988), showed that Neogene (Messinian) gypsum was shipped from central Crete to Akrotiri and Mycenae while Tiryns was supplied with Permian gypsum from one of the sources of the mainland or the Ionian Islands. As noted in Chapter 3, Permian gypsum is cropping on east and west Crete as well, but there is no evidence to suggest that it has been exploited in prehistoric times.

Taking into account the overall Minoan character of the architecture of Akrotiri (Palyvou 1999), the presence of few gypsum slabs is not surprising and given that the stone was transferred by boat its transportation from Knossos to Akrotiri did not require more labour than that needed for its transportation to Pseira, Palaikastro or Zakros.There is no doubt that gypsum continued to be used in the Mycenaean Knossos during the LMII-LMIIA Periods (Halager 1977, Driessen 1999) and it is possible that its elite character was also maintained. It seems that gypsum was valued enough as a stone with a strongly symbolic character, to be transported to Mycenae to dress floors and to be carved to reliefs. Driessen (1990, 1999) has also pointed out the significance of the exports of gypsum to the mainland and the islands and marks Thera, Mycenae and Tiryns as the destinations of the Cretan gypsum exports (Driessen 1990:19, fig.13). I should note here however that according to the study of Gale *et al.* (1988) the gypsum of Tiryns was obtained by a Permian outcrop and since such deposits exist in various locations in the mainland Greece (see Chapter 3, Fig.3.1) we cannot suggest its Cretan provenance.

CHAPTER 7

WEATHERING OF MINOAN GYPSUM

The purpose of this chapter is the assessment of the major weathering factors that affect gypsum deterioration and the clarification and classification of the weathering forms that occur on gypsum with respect to its crystallographic characteristics. The mechanisms that contribute to the development of the weathering forms will also be briefly discussed although not all of them are known and fully understood yet.

The vulnerability of the Minoan gypsum architectural members to weathering has been acknowledged by the excavators of the examined sites as soon as the first gypsum architectural remains were unearthed. After almost a century of exposure to the aggressive environmental parameters, the Minoan architectural gypsum has apparently suffered severe deterioration. The study of the weathering processes aims to gain a better understanding of the chemical and physical mechanisms that are involved in gypsum deterioration, which will ultimately determine the requirements for the establishment of the most appropriate methodology for the conservation and protection of Minoan gypsum in the long term.

Detailed study and analysis of all the mechanisms is not possible within the limits of the present study but at least the fundamental weathering factors and the major weathering forms are being examined.

7.1 Identifying the problem

7.1.1 Early observations on Gypsum weathering

The alarming rate of deterioration of the gypsum architectural elements of the Cretan palaces is evident by the severe damage that can be observed today at the sites that were excavated early in the 20th century. The main problem that was realized immediately after excavation was the effect of water on gypsum rocks. Evans notably wrote: «rain has been found to be deleterious, and in many cases the exposed surfaces of gypsum, simply melt away» (Evans 1928: 352).

There is no doubt that Minoan masons were taking into account the durability of the materials that they were using. Hence gypsum, due to its solubility, was mostly used in sheltered spaces. Although it is never found in outdoors pavements or drainage channels where water flowed almost constantly, it used for lining the 'lustral basins', which were supposed to accept water but not in great quantities since these structures are not provided with drainage. In exceptional cases large structural gypsum architectural members were exposed to an outdoor environment as seen at the facades of the palace and the 'Little Palace' Knossos. Graham suggests that the outdoors blocks, where the exposed surface was vertical, had often been shielded by a thin coat of stucco (Graham 1962:143). However, it does not seem to me that Minoans would cover with stucco stone surfaces that had been first smoothed and finished as for example the great orthostates of the west and east facades of the west wing of the palace.

The gypsum orthostates of the Knossian palace and the Little Palace were protected from the damp and ground water as they were set at some height above the floor level, on projecting limestone foundation courses or *krepidoma*. Moreover, at the Little Palace the wall courses above the gypsum orthostates were continued in limestone ashlar blocks, which were slightly projecting presumably to protect the gypsum below. Also, the narrow strip of limestone placed on the pavement in front of the facade of the North Storage Room protected the gypsum from the rain water (Hatzaki 1994:105).

Evans and Graham have both noted that certain types of gypsum, which were more resistant to water may have been recognized and employed by the Minoans (Evans 1930:288, Graham 1962:104). Their suggestion is based on the presence of gypsum in the interior of the 'foot-bath' in the Caravanserai, (Evans 1928:119) and within the so-called 'lustral basins', where according to some scholars bathing was taking place. Graham notes on the solubility of gypsum: "Gypsum is soluble but... there are many 'buts'. For one thing varieties differ widely. Certain types of gypsum may one have said melt 'like sugar'. Omitting the exaggeration we may admit that some gypsum bases lying out in the weather at Knossos for half a century have been honeycombed by the rain. Other varieties, as Evans himself observed, have an almost unlimited power of resisting the elements. Gypsum blocks are much used in exterior walls, in the great orthostates on the west facade at Knossos and gypsum was actually used for the floor of the foot basin in the 'Caravanserai', in which water stood or flowed constantly. It is also a simple physical principle that the rate of solution is directly related to the area of exposure, so that we may feel sure that the finely smoothed vertical surfaces of the alabaster veneering of the bathroom would resist any normal splashing practically indefinitely. And if by any unlikely contingency the floor slabs needed replacing after several decades of use the Minoan housewife must have felt that the advantages of having a 'tiled' surface were quite sufficient to justify an occasional renewal" (Graham

1962:104).

Graham discusses some very interesting aspects of gypsum weathering such as the variations in the rate of dissolution of different varieties of the rock. However, fine grained gypsum, to which he refers, seems to be more vulnerable to dissolution than selenite which is the main variety used for outdoors architectural elements. Both Evans' and Graham's observations on gypsum varieties and their weathering indicate that they were quite sceptical that the Minoans chose to use quite vulnerable material like gypsum in their monumental constructions and that they recognized the alterations in the structure and the macroscopic characteristics of gypsum as a result of fire. Thus they distinguish between affected and unaffected selenite as originally different varieties, a common mistake that most scholars of this field, including myself, made until a detailed classification and pertographic study was carried out in the course of the present research.

It is likely that the original variety of gypsum blocks that have been 'honeycombed' by rain, as Graham says, were the same as those which Evans thought may have 'unlimited power to resist the elements'. It will be demonstrated in the following paragraphs that dissolution rate and forms can differ considerably between areas affected and unaffected by fire, on the same block.

The effects of dehydration on gypsum blocks were observed by Layard (1849:313) on the gypsum of the Neo-Assyrian reliefs. He noted that "it is extremely fragile, easily decomposes and wears away, if subjected to the action of water or even to damp", and described firing effects on gypsum as follows: "on exposure to fire, this alabaster, becomes of a milking whiteness, as in the ruins of Khorsabad, Kouyunjik and the south-west corner of Nimroud. The outline of the sculptures becomes, at the same time sharper and more defined. They have consequently a more pleasing appearance, than in the grey slabs of the un-burnt edifices, but they crack into numberless pieces, which fall off in flakes, so that it is impossible to move and even frequently to preserve them. The sculptures from Khorsabad in the British Museum show this appearance and are easily distinguished by it from those of Nimroud" (Layard 1849:313, cited at Moorey 1994). It is apparent that in contrast to Evans and Graham, Layard recognized the remarkable change in the appearance of gypsum as well as the weakening of its structure as a result of dehydration caused by fire and was able to correlate the dehydrated textures to the original ones.

7.1.2 Review of the literature on gypsum weathering

Although several studies on gypsum solubility, and gypsum - anhydrite transitions, are reported in chemistry and geology literature, there are very few references on the deterioration of architectural gypsum published in conservation literature.

Zezza (1994) studied the weathering of the architectural gypsum of Knossos with regard to its petrographic characteristics. He identifies two major varieties of the rock, the 'macrocrystalline and nodular' and the 'microcrystalline and laminar' and discusses the variations that prevail on the different varieties, focusing mainly on the typology of the dissolution features known in the geology literature as *karren* forms.

Zezza does not distinguish between burnt and unburned gypsum and considers psuedomorphosed selenites as microcrystalline gypsum. Most of his illustrations of microcrystalline gypsum correspond to selenites that have been affected by fire. As demonstrated in Chapters 5, fine grained gypsum is rarely used by Minoans for outdoors architectural elements and therefore all the large ashlar 'alabastrine' blocks in

Zezzas publication have to be dehydrated selenites. The distinction that has now been made between primary and dehydration textures in Minoan architectural gypsum invites a further examination and classification of the weathering forms, with regard to the original and the present crystallographic characteristics of the stone as affected by fire.

Furthermore, the classification of karren forms needs to be revised according to the recent publications of Macaluco and Sauro (1996, 1996a and 1998) and Macaluco *et al.* (2001 and 2003) who provide a detailed classification of the karren forms as identified on the Messinian gypsum of Sicily, which represents all possible lithofacies.

Papadopoulos *et al.* (1994) studied the effect of crystal size on the geotechnical properties of the Neogene gypsum of Crete. They examine three types of gypsum: 'fine grained alabaster', 'medium sized gypsum of secondary diagenetic origin' and 'large porhyritic selenite crystals' and conclude that the mechanical properties of gypsum are affected by the interlocking efficiency of gypsum crystals and consequently the tensile strength of the crystal bondage. The 'alabaster' gave the best results for compressive, tensile and point load tests while the 'medium-sized gypsum' yielded the lowest values. 'Selenite' showed a comparatively average performance. As regards weathering they conclude that dissolution and temperature affect equally the three different types of gypsum.

However, no numerical reference to crystal size is made in Papadopoulos *et al.* typology and therefore the medium-sized gypsum can include any variety with crystal size from few mm up to a to few cm. Banded, nodular and lenticular and massive selenite can all fall into this category although their petrographic and structural characteristics are quite different. In general, my classification of the varieties of the

Neogene gypsum of Crete is different than that of Papadopoulos *et al.* classification and excludes alabaster.

As it was demonstrated in Chapter 3, no alabaster or any other gypsum of secondary diagenetic origin have been identified in these formations, but it is possible that the 'alabaster' sample which was examined by Papadopoulos *e al.* is a fine grained laminated gypsum or balatino. The 'medium-sized' gypsum, on the other hand, could be a result of dehydration of one of the selenitic varieties which can explain the low mechanical properties of this type. According to the studies of Heard and Rubey (1966) and Murell and Ismael (1976) cited in Kern and Richter (1985), who examined the stress-strain behaviour of massive gypsum, large reductions of strength are observed over a relatively narrow temperature range of 100°-150°C which are attributed to the transformation of gypsum to hemihydrate. The weakening of the dehydrated rock is explained as a result of the increased pore fluid pressure during dehydration which results in the lowering of the confining pressure and the consequent reduction of the cohesive strength of the material.

A study of the gypsum weathering at Knossos along with experimental study of conservation treatments has also been carried out by the Greek Ministry of Culture (Mourtzas 1992). However, these studies have not been published yet and are not available to other scholars for academic purposes.

It has become apparent from the beginning of this research that a more systematic approach to the study of gypsum is needed in order to be able to understand the evolution of its decay, and to develop the appropriate conservation policy, aiming at an effective protection and long-term preservation of the material. There are always risks when applying conservation treatments since their effectiveness can only be tested by time. We often hear that the previous restorer was the most destructive factor of deterioration, although he had considered all the possibilities with the knowledge available to him at this time. One of most representative examples that have been subject to criticism is the restoration and reconstruction of the Palace of Knossos by Evans whose main intention was the preservation and presentation of the site to the public.

For many years in the conservation history, conserving the stone meant intervention on its surface. In recent years though, the increasing awareness of the principle of minimum intervention has led to an increased emphasis on preventive rather than active conservation. Preventive conservation means to control the environmental parameters, which favour the evolution of deterioration processes instead of treating the stone itself. Environmental control, however, is not just limited to parameters such as the temperature or relative humidity. It also includes traffic and pollution control, visitor management, control of ground water, and sheltering of the most fragile parts or even the entire archaeological context.

7.2 Weathering Factors

The term 'weathering factor' is frequently used in stone conservation literature to refer to an agent or action that can cause damage to stone. The term exposure is a broader one and includes all the destructive agents or weathering factors to which the material under study is exposed.

The exposure of Minoan gypsum can be divided in three eras, dominated by different weathering factors acting for different length of time. The first is the exposure of the stone during the occupation of the buildings, including various destructions and rebuilding phases. The second era covers the burial period after the final destruction and abandonment of the sites, during which the ruins were covered by the destruction debris and gradually by accumulated soil. The third era started with the excavation of the sites about a century ago, except for Pyrgos that was excavated in 1975, and the exposure of the ruins to the post excavation environment.

It is well known that stone deterioration is the result of a combination of factors, which are acting together and that no deterioration processes can be attributed to a single factor. However, not all weathering factors are equally important and sometimes identification and elimination of the predominant factors, i.e. the ones which contribute the most to the deterioration processes, can minimize effectively stone decay. Therefore, the identification and evaluation of the weathering factors are some of the most fundamental steps towards the preservation and protection of stone.

The weathering factors are usually examined in four categories according to their origin: the environmental, biological, geological, and human or anthropogenic. The most common factors, which affect stone deterioration, are the environmental ones and especially temperature, humidity, and the content of air pollutants (oxides or salts) in the atmosphere. Biological activity, although examined as a different factor, is largely dependent on the environmental parameters. Geological events such as earthquakes or subsidence are often responsible for major mechanical damages in monuments, which are located in areas with increased geotectonic activity.

Human interaction can cause deliberate damage such as destruction due to warfare, vandalism, or unintended such as the abrasive effect caused by visitors, the inappropriate conservation interventions and the presence of air pollutants originated from the industrial development or traffic. Moreover, it is due to human interaction, namely excavation, that many archaeological sites, including the Minoan ones, are today exposed to all the above aggressive agents. The common factors that affect gypsum weathering are discussed in the following paragraphs.

7.2.1 Environmental parameters

7.2.1.1 Water - Humidity

The effect of humidity on the deterioration of stone monuments is one of the most extensively studied topics in conservation science. Massari in his introductory report at the '*Conference on the problems of moisture in historic buildings*' (*Rome* 1967) states that "at the origin of almost all types of degeneration affecting individual materials is to be found one common factor: water. It is the presence of water which gives rise to the majority of the processes of decay, and water is the parent of all the organic and chemical processes which destroy monuments and works of art" (Massari 1969:27).

Indeed there are hardly any deterioration processes in which water is not involved. Chemical, mechanical and biological deterioration processes are all largely dependent on the availability of water, which acts as an activator. Amongst them are the dissolution of stone components, transfer of salt and other pollutants into the stone body, activation of salt crystallization, freeze-thaw cycles, and biological colonization which are demonstrated in a number of case studies in conservation literature (i.e. Conservation of Monuments in the Mediterranean Basin: Bari 1989, Geneva 1992, Venice 1994, Rhodes 1996, Conservation of Stone and Other Materials: RILEM 1993 etc.).

The basic principles of humidity and moisture transfer in porous materials, such as stone, are discussed in a number of papers and monographs in stone and building conservation bibliography (Ashton & Sereda 1982, Camuffo 1984, 1988, 1991, 1998, Karp 1983, Torraca 1988, Vos 1988 etc.). Relative humidity, which is the factor that is usually examined with regard to stone weathering, is expressed in percent and represents the ratio of absolute humidity to the maximum humidity possible, at a specified temperature. It is an expression of how readily the air will absorb moisture and helps in describing the way in which the atmosphere can affect materials. Surface moisture and condensation are both dependent on the relative humidity as well as the physical and chemical characteristics of the stones surface.

In the case of gypsum, the effect of rainwater is the most obvious factor in deterioration, while water from condensation affects gypsum to a much lesser extent.

7.2.1.2 Temperature

Gypsum, as a hydrous mineral, is quite sensitive to the changes of temperature. The effect of temperature on the structure of gypsum crystals has already been discussed in detail in Chapter 2 and is summarized here. When heated in air gypsum starts dehydrating slowly at about 70°C and then rapidly at 90°C and above. At this first phase of dehydration, gypsum looses three quarters of its water of crystallization and it gradually converts to hemihydrate. The final dehydration starts at about 185°C with the formation of γ-anhydrite up to 250°C, which is successively transformed to β-anhydrite (McConnel 1987, Posnjac 1938).

In continuous heating the transformation of γ-anhydrite to β-anhydrite is completed at about 400-410°C. β-Anhydrite is the stable form of anhydrous calcium sulphate up to 1195°C. Above this temperature it converts to α-anhydrite. With further heating, up to 1385°C, anhydrite dissociates to form CaO and SO_3 (West & Sutton 1954).

The conversion of gypsum to hemihydrate under natural conditions, at atmospheric pressure and temperature of 20°C is possible but takes long geological period of time (Fig. 2.11) while the complete dehydration of gypsum to anhydrite is almost impossible. As demonstrated in Chapter 3 the geological survey of the sources that was carried out in the course of this study showed that secondary alabastrine gypsum is not present in the Neogene outcrops of Crete.

The transformation of transparent selenite crystals into white microcrystalline pseudomorphs, which are preserving the original shape of the former crystal, was observed by experimental heating of crystals under atmospheric pressure.

A 3cm thick selenite slab and 4 single crystals of various sizes (3-5cm long) were heated in a hot air oven at a starting temperature of 60°C and was gradually increased up to 115°C. The samples were removed and observed under the stereomicroscope at hourly intervals. No changes were observed in temperatures below 100°C. The first indications of dehydration were observed under stereomicroscope only after 4 hours of exposure to 100°C. Loss of translucency or whitening of the crystals became visible to the naked eye only after 4 hours exposure to 110°C.

When the temperature reached 115°C dehydration was accelerated and the whitening effect or loss of translucency became apparent. The heating intervals, as well as the observations during heating, are summarized in Table 7.1. The samples where photographed after their exposure to 100°C and 115°C. The change in colour and the loss of translucency of the slab and two large crystals before and after heating is illustrated in (Fig. 7.1).

Temperature is, in general, the major factor in gypsum dehydration. Pressure may accelerate the dehydration process, but at low temperatures, pressure alone cannot activate dehydration (McCormac 1926, Borisenko 1965, McConnell *et al.* 1987).

Due to the crystal structure of hemihydrate, which was described in Chapter 2, the dehydration of hemihydrate is easily reversed under atmospheric pressure and temperature, when exposed to damp air. Hydration of anhydrite however under atmospheric conditions is almost impossible.

X-Ray Diffraction (XRD) of burnt samples from Knossos, Agia Triada and Phaistos showed no traces of anhydrite or hemihydrate, which clearly indicates that gypsum was not completely dehydrated but was converted to hemihydrate which was then re-hydrated. This ultimately implies that dehydration temperature did not exceed 400°C an observation that can be quite significant in the reconstruction of the history of the buildings and mainly the destruction phases.

Apart from precipitation, humidity and temperature a number of other parameters are important to consider, such as wind speed and wind direction, as they can drive marine aerosol or abrasive particles directly to the monuments or simply force evaporation and consequent salt crystallization. Besides, rainfall combined with wind can be much more effective in dissolving gypsum. The frequency of precipitation for each wind direction as well as the rainfall intensity, i.e. the amount of rainfall per day, is more useful for conservation studies but difficult to obtain since the meteorological stations provide information only about the average monthly precipitation values (Camuffo 1991).

7.2.1.3 Atmospheric Pollutants

Air pollutants are all the substances which produce a change in the normal air composition that prevails in rural environments. Therefore, a pollutant can be any kind of substance, which can enter the atmosphere in the form of particles gases or in a mixture of these forms. The mixtures or air with fine dispersed particles, solid or liquid droplets, are known as aerosols. Some of the particles, which play an important role in stone deterioration, are chlorides, metals, carbon, oxides, sulphates, fluorides, silicates, fungi and bacteria.

Pollutants are divided into 'primary' and 'secondary' according to their origin. Primary pollutants are emitted directly from the surrounding environment and include particles, and compounds of sulphur, carbon, nitrogen, low molecular weight hydrocarbons, and others. The most harmful of these are sulphur dioxide, and carbon monoxide and dioxide, produced mainly by the combustion of sulphur containing fuel and carbonaceous fuels respectively. Industrial activity is responsible for the generation of nitrogen oxides, H_2S and several organic pollutants.

Secondary pollutants are the products of interaction of two or more primary pollutants with normal atmospheric constituents. The best known interactions of this type are the oxidation of sulphur dioxide to sulphur trioxide, which is subsequently combined with water vapour to produce droplets of sulphuric acid, or the formation of H_2CO_3, HNO_2 and HNO_3 through similar processes of oxidation of CO_2, NO, NO_2 (Fassina 1988, Torraca 1988: 40-41, Zezza 1996, Skoulikides 2000: 159-182).

The effect of air pollutants on monuments has been the focus of several research projects during the last two decades as a result of the emerging deterioration problems and the need for better understanding of the environment. The most relative to the present research is the EC. Project: '*Marine spray and the polluted atmosphere as factors of damage in the Mediterranean coastal environment*', part of the broader Environment Program of the EC. The project has involved ten institutions from six EC countries and also Malta and Romania and has focused mainly on four pilot monuments, in Athens , Bari, Cadiz, and Malta, which are quite far from each other and cover a broad area of the Mediterranean coast.

The aforementioned research has shown that in the coastal Mediterranean zone marine and continental pollutants are introducing a very aggressive environment on the interface in between stone and air. Marine aerosol is carried directly from the sea by strong winds and storms while the pollutants produced at the coastal zone circulate according to the sea-breeze regime. Dust, smoke, and mist are also deposited on the stone surface, serving as catalysts in the deterioration processes. Examination of the acidity levels of the depositions, suggests that pH levels are much higher in areas of increased industrial and human activities (i.e. Eleusis, Zezza 1996:9). The over all evaluation of the effect of pollutants on the natural processes of stone weathering in the

Mediterranean showed that marine aerosol has the greatest concentration of all pollutants which enter the atmosphere. The distribution of ions of marine origin, Cl-, Na^{++}, Mg^{+++}) and of anthropogenic ones ($SO4^{--}$, NO_3^{-}), collected by the monitoring stations of the pilot monuments, indicate a great disparity in the concentration of marine and anthropogenic ions, the latter forming only one quarter of the total measured amount (Zezza 1996).

Marble, calcite and calcarenites are the main stones that are examined in the above case studies, and are exposed to different environmental conditions and for different length of time. There are few references on gypsum as a product of marble sulphation but not much research has been devoted to the deterioration of gypsum as a natural stone and the effects of the environmental factors on the deterioration processes.

The case studies in the different monuments in the Mediterranean however, offer a good model as regards the methodology and contribute considerably to the understanding of the nature and the interaction of the marine environment in the deterioration of stone in general. In conclusion, these case studies have taught us that the coastal environment of the Mediterranean is very aggressive to stone monuments and that in order to determine the extent to which stone is affected, several environmental parameters need to be monitored. Both outdoor and indoor microenvironment need to be considered, along with analysis of stone weathering products and measurement of the physical properties of the exposed materials. Finally, the collaboration of different disciplines is necessary for the interpretation of the data and the evaluation of the weathering factors.

This study is mainly concerned with the effects of marine aerosol, as it is considered to be the main pollutant in the environment of the examined sites that are all located within a radius of 0,5 to 10 Km from the cost and are therefore all exposed more or less to a marine environment. Pyrgos and Megaron Nirou are located only a few hundred meters away from the coast and therefore the exposure to the marine aerosol is direct. At Knossos, Phaistos and Agia Triada, which are located in larger distances from the coast but not more than 5 Kilometres, the transportation of marine aerosol depends largely on the local climate such as the wind and wind speed direction, the amount of rainfall and the frequency of storms. Industrial activity and traffic are parameters which vary from one site to another. Knossos, for example, receives an average of 3.000 visitors per day during the summer months the great majority of which arrive to the site by car or bus. Hence pollutants such as sulphur and carbon oxides are not a negligible factor in the case of Knossos but is excluded from Pyrgos and is definitely much less at all other sites. Additional pollutants can be brought to Knossos valley from the industrial area of Herakleion, via circulation of air depending on the local environmental parameters.

7.2.1.4 Marine aerosol

Marine aerosols are continually entering the atmosphere in various forms such as film drops, jet drops, sea salt nuclei, sea water particles, brine drops, hygroscopic drop salts, or sea-water drops carried directly from the sea by winds. Salts of marine origin such as chlorides, which affect the most gypsum deterioration, are abundant during the winter, while carbonates and silicates of marine origin are the main components of the particles which are deposited during the summer (Zezza 1996).

In coastal areas marine aerosols are carried directly from the sea by strong winds and indirectly by rain. The combination of sea salts, water movement and evaporation can be very aggressive to the stone causing mainly mechanical damage related to salt dissolution-crystallisation cycles. The morphology of the weathering effects varies according to the physical properties of the stone and the environmental parameters under which the salt activity is taking place. The most common weathering features that can be attributed primarily to salt crystallisation cycles are the efflorescence, subflorescence, exfoliation, flaking, and cracking.

An additional effect of marine aerosol to the deterioration of gypsum is the enhancement of its solubility (Fig. 2.14). The increase in solubility of gypsum in seawater owes to the high concentration of NaCl and $MgCl_2$ in the solution (Table 7.2). As already noted in Chapter 2.1.3, the solubility of gypsum in the presence of NaCl is enhanced due to a decrease in the activity coefficient and an increase of $Na_2SO_4^-$ complexation. In $MgCl_2$ solutions the solubility is increased even more. This is due to a greater ionic strength and greater association of $MgSO_4$ in relation to that of $Na_2SO_4^-$ (Fig. 2.15) (Posnjak 1938, 1940, Tanji 1969: 659, Klimchouck 1996).

7.2.1.5 Climate of Crete

Climatology is mainly concerned with the frequency of specific environmental phenomena, as the climate is better characterized by the repetition of certain environmental events. However, the meteorological data is usually expressed in average values which are not as useful for the study of stone deterioration as the extreme values and their frequency (Camuffo 1991, 1998:298).

Consideration of environmental data of a long period of time, at least a couple of decades, is necessary in order to understand the climate around the sites and to observe the repetition of certain phenomena which are likely to affect stone weathering.

The climate of Crete is typically Mediterranean-semiarid with clearly defined seasons. Winters are cool and humid while summers are hot and dry. During winter westerly winds prevail which bring rain from the Atlantic, while in the summer the winds are northerly and bring moisture from the Aegean Sea.

Environmental data is being recorded on Crete since the beginning of the twentieth century by several different stations. The stations that can provide useful data for this study are the Herakleion, Tymbaki and Ierapetra. The data from the Heraklion station characterizes the climate of the Knossos and the Megaron Nirou area being probably closer to the latter, since the station is close to the sea and therefore correspond more closely with coastal environment of Megaron Nirou than that the Knossos valley. The Tymbaki station provides data for the Phaistos and Agia Triada region while the data from Ierapetra characterizes the region of Pyrgos (Pennas 1977, Roberts 1981, Rackham 1996, Shay 2004).

For the purposes of this study environmental data from the three stations was obtained from the Hellenic National Meteorological Service, Directory of Climatology. The data includes monthly values of mean, average minimum and maximum, absolute minimum and maximum temperature mean monthly relative humidity, maximum monthly precipitation, cloudiness, and prevailing winds for a period of 37 years from 1959 to 1996. Detail environmental data from all stations for a period of 60 years from 1915 to 1975 has been analyzed and discussed by Pennas (1977).

When comparing Pennas's data with the data from the following 21 years (1975-1996) that was obtained from the Meteorological service, there are no significant shifts observed in the climate. Variations in the monthly values of mean ambient temperature from the Tymbaki station, for example, are less than 0.5°C, in the average maximum temperature are less than 0.8°C and in the average minimum are less than 0.4°C. Similarly, small variations are observed in all the environmental parameters of the other stations as well. Pennas's data, as well as the latest data were plotted in graphs that present a period of 81 years from 1915-1996 and are presented in Fig.7.2 for Herakleion, Fig.7.3 for Tymbaki and Fig.7.4 for Ierapetra.

It is apparent that there are no radical differences in the environmental data of the three stations. The lower average temperatures are 7-8°C, recorded during January and February with sporadic frosts. The higher average temperatures are 20 – 25°C recorded in July and August, occasionally reaching absolute maximum values of 45°C. Relative humidity values in Herakleion, fluctuate between 58-60% while in the other two stations, fluctuate between 50-70%. The higher relative humidity values that are recorded in Herakleion in the summer season are attributed to the sea water vapour driven by the north winds that prevail on the island in this period of the year.

Annual precipitation is 434-481mm in Herakleion, 480-483mm in Tymbaki and 496-545 in Ierapetra, most of which falls between November and March in quite intense downpours (Pennas 1977, Shay 2004).

Due to the particular characteristics of gypsum, temperature and precipitation are the major factors that affect its weathering processes. Besides, the intensity of rainfall is quite significant since the rate of gypsum dissolution is strongly depended on the water flow velocity (Klimchouk 1996). Relative humidity is also important but does not affect weathering in such a dramatic way as the direct rain water.

The environmental data provided from the meteorological stations can only give us a general idea of the broader environment of the examined archaeological sites, but in order to asses the influence of the specific environmental parameters on gypsum weathering we need to define microclimate to which the Minoan gypsum is exposed. For example, the exposure of the stone to the sunlight during day may result in condensation-evaporation cycles, but the values of temperature and relative humidity that are provided by the meteorological stations can help in identifying and predicting such a process.

In order to define the microclimate to which gypsum is exposed, we need to monitor several environmental parameters and to regularly observe and interpret the data. Such a detailed environmental study is not within the purposes of the present research, however, an attempt has been made to sample the major environmental parameters which affect gypsum weathering, Temperature (ambient and surface) and Relative Humidity (ambient) at Knossos was monitored in order to understand the extent to which they may affect gypsum weathering. Surface Temperature is interesting not only with regard to condensation that contributes to the dissolution and crystallization of soluble salts and of gypsum itself, but also to the thermal stability of gypsum.

7.2.1.6 Environmental Monitoring at Knossos, August 1998 – July 1999

Environmental monitoring started on 4th July 1998, at the Palace of Knossos, as part of my study on the weathering of architectural gypsum. The major aims of this work were to determine the maximum temperatures that can be reached on the surface of gypsum in order to verify whether dehydration of gypsum can take place under natural conditions of exposure, and to investigate the possibility of condensation being involved in the development of efflorescences and subflorescences, which are major weathering forms that occur in the reconstructed areas of the buildings. Due to the high solubility of gypsum and the fast dissolution kinetics, condensation can cause substantial dissolution in sheltered or closed environment (such as caves Klimchouk 1996a) but in an outdoor environment, where the direct effect of rain water is very intense, condensation is only a minor factor in the dissolution process.

For the purposes of this study, three sets of digital data loggers were installed on site.

The first set was installed on one of the orthostates of the West Façade of the Palace in order to monitor the outdoors environment. The set includes an ambient temperature, a surface temperature (with external probe) and an ambient relative humidity logger (Fig 6.5).

The second set was installed in the Temple Repositories in order to monitor the environment under the light shelters. This set includes an ambient temperature and an ambient relative humidity logger (Fig.7.5).

The third set was installed in the Lustral Basin of the Throne Room in order to have some sample measurements of RH and T in the heavily restored areas. The third set included ambient temperature, surface temperature and relative humidity loggers (Fig.7.5).

The following codes were given to the different loggers:

T-OTD: Ambient temperature in outdoors environment.

PT- OTD: Surface temperature in outdoors environment.

RH-OTD: Ambient relative humidity in outdoors environment.

T-SLT: Ambient temperature under light shelters.

RH-SLT: Ambient relative humidity under light shelters.

T-RST: Ambient temperature in restored room (Lustral Basin, Throne Room).

PT-RST: Surface temperature in restored room (Lustral Basin, Throne Room).

RH-RST: Ambient relative humidity in restored room (Lustral Basin, Throne Room).

All loggers were initially programmed to take measurements every 30 min for one week. The probe of the PT-100 logger was installed on the gypsum surface with adhesive tape. For the second series of measurements, the PT-100 was installed on the gypsum surface with thermo-conductive paste and was covered with thin polystyrene foam. After a week the data was downloaded and compared to that which was obtained from the same spot by the ambient temperature logger, in order to evaluate the method of its installation on the stone surface. A considerable difference, one of about 15°C in between the two loggers, was recorded where the PT-100 gave the lower measurements. This result did not seem reasonable as the temperature that developed on the stone surface, that was exposed to the direct sunlight, was expected to be somewhat higher than the ambient. Therefore, the logger was this time attached on the surface with thermo-conductive paste and masking tape without the polystyrene foam. The data was downloaded once a month and the loggers were installed again always with the same settings, taking measurements every 30min.

During the 13 months of recording the RH loggers showed some technical problems due to the high RH values to which they were exposed. In general, it seemed that the readings of the sensors, when relative humidity reached levels above 80%, were not reliable. The RH loggers which showed technical problems were removed to be cleaned or sent to the supplier for calibration, therefore this has resulted in some gaps or inconsistencies in the data. In addition to this there was some loss of data due to failures in downloading. The loggers were removed and cleaned every three months and tested under the same conditions in order to evaluate their performance. A difference 5°C plus or minus was observed at the readings of the Temperature loggers and a 10% plus or minus for the RH loggers after thorough cleaning and drying. The RH loggers have proved to be very sensitive, as the accumulation of hydrophilic materials (dust, soil) on the sensors can easily affect their accuracy.

Despite all the difficulties and the technical problems of this work the data that was gathered gives an idea of the microclimate in the different areas of the palace and its effect on gypsum weathering. The temperature values measured on gypsum surfaces in outdoor environment were not high enough to initiate natural dehydration of the material. The data that was obtained from the ambient humidity and surface temperature were used for the calculation of the dew point. The dew point is the temperature to which unsaturated air must be lowered at constant pressure in order to give 100% moisture and therefore condensation of water vapors occurs when surface temperature reaches the value of the dew point. It can be computed from the RH and T values with the help of the following equations:

DP=(236,9*LN((RH/1000*EXP((17,25*T)/(236,9+T))))/

(17,25-LN((RH/100)*EXP((17,25*T)/(236,9+T) (after Karp 1983)

DP=((237,3+T)/7,5)*(LOG(RH/100))+T (after Camuffo 1998:75)

DP=237,3*((237,3*(LOG(RH/100))+T*LOG(RH/100)+(7,5*T))/

(((7,5*237,3)-(237,3*(LOG(RH/100))-(T*(LOG(RH/100)))))) (after Camuffo1998:76)

The above formulas were all applied for the calculation of the dew point and the results were compared. The first formula showed the lowest value, the second formula produced values slightly higher with a difference of 0.1-0.30°C, whilst the third formula showed the highest values with a difference of 0.5-0.70°C.

The calculated values of the dew point were plotted with the temperature values in order to detect possible condensation events. The results are illustrated in a series of 50 graphs where Temperature, Relative Humidity and Dew Point for each month and each monitoring location, from August 1998 to July 1999, have been plotted and of which only the most significant ones are presented here. The Dew point has been calculated only for the areas and the months where the data was complete. Only one surface temperature data logger was available, which was installed for the first months in an outdoor environment and then in the Lustral Basin of the Throne Room for the rest of the time. The data from the ambient temperature loggers was applied for the calculation of the dew point in the locations where surface temperature was not available, therefore it should be stressed here that this data cannot be taken as accurate and precise. However, in sheltered and restored areas where the surface of the stone is not directly exposed to the sun light the surface temperature of the stone is not very far from the ambient temperature. Condensation has obviously occurred at the areas where the dew point curves meet or are close to the curves of the measured temperature.

During the cold winter months, the temperature values in the sheltered and restored areas are above the dew point threshold while in outdoors environment the temperature meets the dew point frequently almost on a daily basis (Fig.7.6-7.7). Considering that the accuracy of the data loggers can fluctuate 5^{o} degrees plus or minus for the temperature ones and almost 5% for the relative humidity ones and that the temperature in the Sheltered and the restored areas is sometimes close to the dew point threshold (Fig.7.7), I assume that condensation occasionally occurs in these areas as well.

The environmental data of the spring and autumn months is quite similar and indicates that condensation occurs less occasionally in outdoors environment and that in the restored and sheltered areas the temperature is well above the dew point threshold and therefore condensation does not occur at all at there areas (Fig.7.8-7.9).

During the summer months condensation occurs occasionally in sheltered and outdoors environment (Fig. 7.10-7.11).

In conclusion, the environmental data recorded indicates that the environmental parameters favour the condensation of water vapour on the gypsum surfaces that are exposed to outdoors environment throughout the year being more frequent during the winter months. In the sheltered areas condensation occurs occasionally in the winter and summer months, while in the restored parts of the building condensation may occasionally occur during the winter months only. It should be acknowledged here that the outcome of this monitoring is only a small sample of data and indicates a need for verification of the environmental parameters through a series for measurements and at several locations before we are able to determine the microclimate in the different parts of the building.

7.2.2 The biological factor

During the first macroscopic observation of gypsum archaeological remains and natural outcrops the biological deterioration of gypsum was noted as one of the most intense phenomena in outdoor environments which required a closer examination. The effects of biological micro-organisms on stone have been discussed quite often in bibliography with regard to the physical and chemical processes that they are involved in. Griffin *et al.* (1991) gives an account of the predominant biological species and their effects on stone surfaces. Further, they site several case histories and discuss the results of past conservation treatments against biological growth. Warscheid and Braams (2000) also provide a thorough review of the biodeterioration of stone and emphasize on the practical implications on stone conservation.

Microbiological colonization or biodeterioration of stone refers to its physical and /or chemical damage, which is caused or affected by biological organisms. It is usually related to physical or mechanical damages, such as the detachment of crystals due to penetration and expansion of biological growths in the crystal boundary fractures, or the enhancement of existing cracks. Chemically induced damage due to biological organism's metabolic processes is also expected as the biological deterioration is usually a combined effect of physical/mechanical and chemical processes. Although there are no distinctive weathering features which can be solely attributed to biochemical action or to bio-deterioration, most weathering features appear as a result of various environmental factors amongst which are the biological growths (Jones and Wilson 1985, Griffin et. al., 1991, Warscheid 2000).

7.2.3 Human interaction

The excavation and past conservation and restoration interventions that were carried out in the first half of the 20th century both human induced factors, have affected dramatically the preservation of the gypsum architectural members at the examined sites and especially at the palaces that have been subjected to several excavation and restoration phases. The present state of preservation of Minoan gypsum varies from site to site and is largely dependent on the measures that were taken by the excavators and the archaeological service for its protection.

Evans immediately acknowledged the problem of the severe gypsum weathering due to dissolution by rain water and constructed temporary wooden shelters over the most important parts of the Knossos palace, namely the Room of the Throne and the Domestic Quarter, soon after their excavation. The first roof was already constructed in 1901, immediately after the end of the first excavation season, over the remains of the Room of the Throne as an urgent measure for the protection of the gypsum floors (Brown 1994:41). His main goal at these early stages of his work was the protection of the gypsum decorative and structural elements.

It was only later, after the end of World War I, that Evans proceeded into the large scale restoration works, using reinforced concrete that was the new revolutionary technique at the time. The main goal of this second phase of his work was the 'reconstitution' of the main sections of the palatial complex and its presentation to the public, a work that was the subject of vigorous criticism from his contemporaries as well as later scholars up to the present. Regardless of the character and the purpose of these extensive restoration works, Evans has definitely been successful in protecting the most significant gypsum decorations of the palace from the effects of the aggressive environmental elements and the dramatic difference in the preservation between the sheltered and unsheltered gypsum elements is the ultimate proof of it.

After World War II, the Archaeological Service of Herakleion (ΚΓ' Ephorate of Prehistoric and Classical Antiquities) started a new conservation and restoration campaign at Knossos and Phaistos. Various transparent surface coatings were for the first time applied to gypsum surfaces, but were proved to be insufficient to protect it, while at the same time the surface was discoloured and became quite slippery and therefore dangerous for the visitors who were, at that time, still allowed to walk on the gypsum floors of the Domestic Quarters and the Grand Staircase. Furthermore, the coatings began to flake soon after their application and needed to be replaced quite often

(N. Platon 1961, Karetsou 2004).

In view of the difficulties in the conservation and protection of gypsum, a decision was made by the Archaeological Service of Herakleion, directed by N.Platon at the time, to replace the most weathered gypsum slabs with new ones, as already practiced at Phaistos by Levi. The same practice was followed in the 1960s by the next director S. Alexiou. In most areas the missing parts of the floor and wall slabs were filled in with cement based mortar while most of the weathered blocks and doorjamb bases were topped with cement mortar as well (Fig.7.12a-c) (N. Platon 1950, 1951, 1953, Alexiou 1962, 1964, Levi 1976, Karetsou 1995, 2004).

Levi justified the decision made for the replacement of the original floors as a secure and correct solution to the problem of the severe deterioration of the original slabs. He emphasizes that gypsum slabs are not 'artistic creations' ('non di creazioni artistiche' Levi 1976: 3) and therefore their replacement would not alter the character of the building and no mistakes could be made in the reproduction of the gypsum slabs, and adds in a parenthesis: (in contrast to what happened in other Minoan Palaces, including that of Knossos). It is apparent here that Levi discretely criticizes the work of Evans at Knossos, who despite the mistakes or exaggerations that he may have made in the reconstructions of the palace, was at least concerned with the preservation and protection of the original architectural elements. Levi, N. Platon and Alexiou, on the other hand, were more cautious in their restoration works but not really concerned with the preservation and the protection of the ancient fabric itself. In the photos that were obtained from the archive of the Italian School of Archaeology at Athens and were presented in Chapter 5, it is obvious that the original floors in the domestic quarters of Phaistos were almost complete and despite the fragmentary state of the gypsum slabs, they could have been preserved and protected by a shelter. Instead of that the majority of the slabs were replaced by modern ones and then later on a shelter was constructed in order to prevent the deterioration of the new floors.

The conservation and protection measures that were taken in the past and the different conservation approaches that were adopted during the long history of conservation, restoration and renovation of two palaces, which could be the subject of another thesis itself, will not be discussed further here, however, it is necessary to emphasize the fact that human interaction and especially excavation and conservation/restoration treatments have definitely played a major role in the present state of preservation of their gypsum remains. When comparing specific structures that were excavated at about the same period, the preservation of those that have been sheltered either by light shelters or by concrete roofs and those that are unsheltered, one realizes that the splendour of Domestic Quarters of Knossos with the multiple flight Grand Staircase would hardly be imaginable (Fig. 7.13 a-c).

7.2.3.2 Visitors-Vehicle Traffic

Due to its softness, gypsum is quite vulnerable to abrasion stresses. Statistics from the last two decades show an increasing amount of visitors at the examined sites. Especially at Knossos, the second most visited archaeological site in Greece, the number of visitors per year is above a million people (Karetsou 2004). Phaistos receives nearly 200.000 visitors, Agia Triada slightly less, while Pyrgos and Megaron Nirou are visited by far less people.

The increasing traffic of visitors is adding to the weathering of gypsum floor slabs, thresholds, staircases and other horizontal surfaces. The effects can be seen in the different parts of the palaces, which have been open to the public for different lengths of time. The most striking examples are found at Knossos and at Phaistos where the floors and the staircases were exposed to visitors until recently. The floors of the domestic quarter of Knossos for example, where open to the public until 1992 without any provision for the protection of the floors show severe weathering features such as granular disintegration and crumpling although protected by the harmful effects of rainwater (Fig.7.14).

7.2.4 Evaluation of weathering factors

Careful examination of the most common factors that are involved in stone deterioration demonstrate that they all contribute to the weathering of gypsum to some extent. Rainwater is the main weathering factor in the outdoors environment and especially on surfaces that are exposed directly to it. The presence of salts and other pollutants in the atmosphere, which are dissolving in water to give a saline or acidic solution, enhances dissolution. Strong winds drive abrasive particles onto the soft surface of gypsum resulting in the loss of surface grains. Dry winds are also very effective in forcing thermo-hygrometric cycles. High levels of relative humidity on the other hand, favour the dissolution and movement of soluble salts as well as of gypsum itself. Solar radiation is partly responsible for thermally induced mechanical stresses, and the evaporation and crystallization of gypsum and other salts into the pores and fissures of the rock, or on its surface. Long exposure to temperatures above 70°C can also activate dehydration-hydration cycles but such temperatures can't be reached in outdoors environment in any of the examined sites and should therefore be examined as a result of fire during the destruction of the buildings or at some other time in the building's history. The temperature values that were recorded over the summer are not maintained in high enough values to initiate transition of gypsum to hemihydrate.

However, this is also evident from the observation of gypsum faces that are exposed around the outcrops. There are no apparent natural dehydration features at the outcrops, while on various spots one can easily identify small fires on gypsum rocks by the whitening of the crystals and the formation of pseudomorphs. The extensive cracking of gypsum blocks however, is observed on unaffected selenite as well as on affected and therefore it can't be solely attributed to the volumetric changes of gypsum during dehydration.

Wetting–drying cycles are partly responsible for the expansion and contraction of clay minerals that are distributed in the inter-crystal contacts and the dissolution and re-crystallization of gypsum itself. Fissures that are initiated either by expansion of clay minerals or by volumetric changes during dehydration are then extended with the deposition of soil and the development of biological colonization. Mechanical damage is certainly caused by the penetration of the lichens hyphai into the crystal contacts and by the expansion of the thallus under changes of humidity. Lichens can also cause chemical damage by excretion of oxalic acid, carbonic acid and other acids capable of reacting with metal ions such as calcium. Bacteria can also attack chemically; autotrophic bacteria are oxidizing sulphur and nitrogen compounds, to produce sulphuric acid and nitric acid respectively. Heterotrophic bacteria on the other hand, produce weaker organic acids. Colonization of higher plants causes further mechanical damage as the roots of the plants penetrate into the pre-existing cracks and the fissures of the rock.

Frost is rare on the coastal areas of Crete where average daily temperature in the winter is around 9°C. Finally, natural disasters such as earthquake activity or earth subsidence have certainly played an important role in the mechanical damage of the building and its constituent materials as demonstrated by the archaeological data (i.e. successive destructions due to seismic activity and rebuilding are frequently recorded in different chronological periods).

7.3 Weathering Forms

Weathering is an overall effect of several factors acting together. The morphology of weathering depends on the nature of the stone, the microclimatic conditions created on its surface, and the deterioration mechanisms involved. In most cases several deterioration processes are operating together in order to form a distinctive weathering feature. Detailed recording and classification of the weathering forms was undertaken, at representative sections of the examined buildings, with an attempt to correlate the weathering morphology with the physical and chemical characteristics of the stone such as composition, structure, crystal size, and the environmental parameters of the surrounding microclimate.

Assessment of the weathering state, diagnosis of the causes and the mechanisms of deterioration, as well as surface study as regards alterations of the relief and the colour, the nature of surface deposits and the detachment of crystals, were studied by means of macroscopic observation and analytical methods such as, Polarized Light Microscopy (PLC), Scanning Electron Microscopy (SEM), and X- Ray Diffraction (XRD).

7.3.1 Classification of weathering forms

The following paragraphs will present the predominant weathering forms that have been identified on the Minoan gypsum remains, using the classification scheme that has been proposed by Fitzner *et al.* (1995). As already mentioned in the above paragraphs, weathering is the result of a combination of factors and therefore a precise correlation of weathering forms, factors and processes is not always possible. The aforementioned classification scheme is based mainly on geometrical and phenomenological criteria.

Furthermore, due to the particularity of gypsum, being a hydrous mineral that is examined in the literature in various different perspectives i.e. as a mineral or rock, as a crust on calcareous stones or as a salt appearing on stone masonry or wall painting, it has been quite difficult to describe the weathering forms after a single classification scheme. Thus, some of the weathering forms such as the fissures independent of the stone structure and the surface dissolution patterns are being described and explained after the classification scheme of gypsum crust and *karren* developed by Macaluso and Sauro (1996, 1998) and Macaluso *et al.* (2001, 2003).

An internet-accessible multilingual illustrated glossary on stone deterioration is currently being developed by the ICOMOS International Scientific Committee for Stone (ISCS) aiming at the establishment of a common language that will help to overcome the major communication problems between scientists and conservators (Vergès-Belmin 2004). Unfortunately, access to the site is not possible yet and therefore it was not possible to correlate and perhaps adjust the terminology being used in this study, to that of the ICOMOS-ISCS glossary.

7.3.1.1 Dissolution or *Karen* forms

Dissolution has always been considered the most important factor in gypsum weathering. Dissolution flutes or 'karren forms' are the predominant weathering forms that occur on gypsum in an outdoor environment. This is evident in all archaeological sites and at the exposed faces of the rock at the outcrops, where various dissolution forms can be seen mostly on fine grained gypsum.

The term karren refers to channels or furrows caused by dissolution on massive bare mainly limestone surfaces. They vary in depth from a few mm to more that a meter and are separated by ridges. In modern usage the term is general describing the total complex of superficial solution forms (Malcom 2002).

A detailed classification of karren forms that occur specifically on gypsum with reference to the Messinian gypsum formations of Sicily is provided in a series of publications by Italian geologists (Macaluso and Sauro 1996a, 1998, Macaluso *et al.* 2001 and 2003). According to this classification scheme the *karren* forms are divided into four categories with respect to their size and shape:

i) nano-forms with all dimensional parameters less than 1mm,

ii) micro-forms, with two of the three dimensional parameters (length, width, depth) in the order of one to a few mm with volume less than 1cm^3. Micro-forms are represented by micro-rills, micro-ridges, micro-meanders, micro-pits and micro-conduits.

iii) small forms, with two of the dimensional parameters in the scale of cm but less than 1m in general. The small forms are represented by mini-rain craters, *rillenkarren*, mini-spitz or mini-spikes, dissolution levels, heel-print karren, scalp-like karren, meandering rills, dissolution runnels, meandering runnels and flared runnels and solution levels.

iv) meso-forms, with two of the three dimensions in a scale between 1 and 10m.

The forms that have been identified on gypsum surfaces according to the above classification are the following:

Micro-rills: very small, almost linear grooves 1-2mm wide, several cm long and less than 2mm deep, with a U-shape section. They occur mainly on fine grained laminated gypsum but also to all the varieties that have been affected by fire (Fig.7.15-7.17).

Mini-craters: crater-like depressions with a diameter of 12-30mm and depth of 1-

30mm. They can be observed on several horizontal surfaces of fine grained gypsum and selenites affected by fire in a slightly larger size up to 1cm. According to Macaluso and Sauro the crater are formed due to 'splash dissolution': Fine drops, resulting from forthe intense fall of rain in the solution that is collected in the crater, are ejected towards the slopes of the rills, resulting in mass transfer of the ions in solution and possibly secondary precipitation or crystallisation on the ridges (Fig.7.17-6.20) (Zezza 1994, Macaluso and Sauro 1996).

Mini-craters occur in all fine grained unaffected and affected varieties of Minoan gypsum. Their morphology is similar to that of the alveolar weathering which is probably the reason why Zezza (1994) used the term 'corrosion alveoli' to describe the assemblages of these small craters. However, alveolar weathering is mostly known as a wind driven effect and therefore it seems more appropriate to adopt the term of Macaluso and Sauro.

Rillen*Karren* or rills: shallow channels separated by ridges, ranging from few mm to few centimeters in width and depth and can be several cm long. It is the most common karren form that occurs on all gypsum varieties that are exposed to rain water. Rills are formed due to the concentrated flow of water in the centre of the depression. According to Macaluso and Sauro 'splash dissolution' also contributes to the development of the rills, focusing dissolution at the centre of the flutes. The rills are separated by ridges that are often quite sharp edges that are termed mini-spitz (Fig.7.21-7.23a-b)

Mini-spitz or minute-spikes: are miniature sharp peaks that develop between mini-craters or rills, and occur only in alabastrine and laminated (balatino) gypsum (Fig.7.15-7.16).

Runnels (Makacuso and Sauro 1996, 2001) **or *rillenkarren*** (Malcom 2002) **or solution grooves** (Zezza 1994): round bottomed grooves that are larger than the rills and show a mostly U-shaped section. They are formed by the concentrated flow of water and occur in both fine and coarse grained varieties. The width and depth of the runnels depends on the crystal size of the gypsum variety on which they develop. Their size depends on the size of the crystal (Fig.7.24-7.28).

Meandering rills: small winding or meandering channels in the size of rills. They occur on balatino and alabastrine gypsum (Fig.7.29-7.31). Meandering rills are probably formed through mechanisms similar to those that operate during the formation of rills. The presence of foreign grains, i.e. soil, sand or inclusions in the rock that interrupt the linear flow of water, seem to be responsible for the development of the meandering flutes.

Dissolution levels (Macaluso and Sauro 1996) **or solution pan** (Malcom 2002)**, rock tanks or *kamenitse*** (Zezza 1994)**:** horizontal surfaces, of various shapes, not related to the bedding planes. According to Macaluso and Sauro (1996) these levels are produced by diffuse dissolution from a homogeneous water sheet flowing slowly across the surface. Solution levels are commonly found at the affected selenite blocks at Knossos (Fig.7.32-7.33). These pans or levels are often filled with soil and biological growths (Fig.7.34).

Boxwork forms: These are dissolution forms that develop due to selective dissolution when small dikes or veins of less soluble material are present. The most common of those are polygon pans or closed depressions and dissolution levels that are outline by less soluble material (Fig.7.35). Laminations of less soluble material are also often observed on balatino gypsum (Fig.7.36a-b).

The development of the above forms is dependent on the crystal size of gypsum. The microforms only develop on fine grained varieties while some of the small forms can also develop on medium and coarse grained gypsum. The meso-forms develop equally on all kinds of gypsum. In general all these forms are more apparent on fine grained varieties and pseudomorphosed selenites.

A very characteristic feature that is frequently observed on partly affected selenite blocks is the difference in the predominant weathering forms between the affected and unaffected part of the block. Karren forms usually prevail in the affected pseudomorphosed and therefore fine grained part, while granular disintegration prevails on the coarse crystalline unaffected part (Fig. 7.37-7.38).

The solubility of all kinds of gypsum is the same but dissolution velocity is also depended on the grain size. *In situ* macroscopic observations indicate that dissolution is more intense on fine grained gypsum (balatino) or on pseudomorphosed selenite surfaces. Vertical massive selenite surfaces that are not affected by fire are in a remarkably good state of preservation as already demonstrated throughout Chapter 5. Observation of samples in thin section under the petrographic microscope has shown that areas with smaller crystals have dissolved more and show increased porosity when compared to others with larger crystals (Fig.7.39) Furthermore, porosity is usually enhanced towards the surface due to the higher supply of water at the outer layers of the rock (Fig.7.40).

Dissolution velocity is also accelerated significantly under force movement of water and therefore dissolution patterns are always more intense on the horizontal surfaces that are directly exposed to the rain and concentrated flow of water (Chapter 2, Fig. 2.17) (Klimchouk 1997).

This is evident on the floor slabs of Megaron Nirou, were the water that is dripping through the holes of the shelter have caused severe concentrated dissolution. In most cases the dissolution cavities have penetrated through the entire thickness of the slabs. This is a result of combined dissolution and granular disintegration especially on unaffected selenite where granular disintegration is more intense (Fig.7.41). The same effect is apparent in the Palace of Knossos, on the corridor that leads from Queens Megaron to the Room of the Plaster Couch, as well as in some of the corridors at the west magazines where the water that drips through the cracks of the concrete slab of the roof is enriched in electrolyte ions which enhance dissolution (Fig.7.42).

Finally, as pointed out in Chapter 2, the dissolution velocity differs on the three different planes of the crystal (010, 110, 111) in the ratio of 1:1.76:1.88 respectively, which implies that dissolution is more intense on surfaces that expose the (111) and (110) face of the crystal than the plane of perfect crystal (101) (Scholander 1952). Thus, in well oriented vertical selenite the surfaces that are vertical to the crystal growth direction show more intense dissolution than the parallel ones (Fig.7.43).

7.3.1.2 Granular disintegration into rudite

Fitzner at al. 1995, define granular disintegration as the detachment of grainy stone particles, individual grains or grain aggregates. It is subdivided in three categories according to the size of the crystals that detach: granular disintegration into powder, into sand and into grus, for grains that are not visible to the naked eye, small grains, and larger grains respectively. However, for the detachment of larger crystals the granular disintegration into rudite is used here instead of 'granular disintegration into grus'. The latter is a term that usually refers to the weathering of magmatic rocks and their disintegration into fragments and mineral components (Fitzner *et al.* 1995:64, Migon 2002) and therefore it seems more appropriate to introduce a different term that refers specifically to the detachment of large crystals regardless of the kind of stone in order to be more precise and to avoid misinterpretation. The geological term 'rudite' refers to grains larger that 2mm and therefore seemed a more appropriate one for the description of this weathering form, which appears mainly on unaffected selenites.

It is the predominant weathering form that occurs on unaffected primary selenite blocks and slabs that are exposed to outdoors environment. It can be observed mainly on the horizontal surfaces of selenite ashlar blocks and slabs at the palace of Knossos (Fig 6.44-6.45). The same feature is repeated at the Little Palace and the buildings around Knossos and to a lesser extent at Megaron Nirou and Pyrgos.

Granular disintegration is the result of a combination of different factors: gypsum crystals or pseudomorphs become loose due to dissolution of the clays and/or carbonates from the inter-crystal boundaries and of the crystals themselves and gradually detach from the main body of the rock. Dissolution of gypsum and/or clay and/or carbonate along the crystal boundaries has been observed on most of the unaffected and pseudomorphosed selenites that were examined in thin section (Fig.7.46-6.50).

The dissolution in the inter-crystal space is followed by accumulation of secondary soil deposits in the voids and finally colonization of algae, lichens, mosses and higher plants. The penetration and expansion of the biological growths in the crystal boundary fractures contributes to further detachment of crystals or larger parts of the rock (Fig.7.51-7.52). Furthermore, additional abrasion stresses caused by visitors' traffic on site accelerate the detachment of the already loosened crystals. Granular disintegration often shows transitional forms to crumbling and contour scaling (Fig.7.53-7.54).

Granular disintegration into powder may take place in fine grained varieties and pseudomorphosed selenites but it is not visible with bare eye and therefore it cannot be recognised on site. Besides the *Karren* forms are so prominent on these varieties when they are exposed to the rainwater that other types of weathering can hardly be noticed.

7.3.1.3 Loss of translucency

The loss of translucency in the selenite crystals has already been explained in Chapter 2 and in paragraph 7.2.1d, as a result of the phase transitions of gypsum to hemihydrate (or bassanite) (Chlouveraki 2002, 2003, Lugli 2002). Hemihydrate easily re-hydrates but the gypsum that derives from its hydration has a microcrystalline structure that resembles alabaster. The crystalline lattice of primary gypsum can be preserved during dehydration, resulting in a pseudo-structure that indicates the initial shape of the primary crystal. This alteration macroscopically results in the loss of translucency of the initial crystal (Fig.7.55a-b and Fig.7.56a-b).

As demonstrated in Chapter 3, macroscopic observation of several hundreds of blocks and slabs of gypsum and microscopic examination of 62 representative thin sections under polarized light microscope, showed that alabastrine gypsum is a result of alteration of primary crystals due to dehydration caused by fire and was formed by burning of either massive, banded or nodular and lenticular selenites.

This effect is more obvious on the partially burned gypsum blocks at Knossos, where the original selenite crystals are pseudomorphosed by white alabastrine gypsum. The coexistence of primary and pseudomorphosed selenite crystals on the same architectural element is a common feature. The most representative examples of it are the orthostates of the west and south façades at the palace of Knossos, the large doorjambs and the partition jambs of the west porch, as well as the orthostates of the south façade of the Little palace. It can also be seen on the selenite ashlar blocks of the light well and of the south façade of Myrtos Pyrgos (Fig.7.57-7.59).

7.3.1.4 Gypsum crust

The term 'gypsum crust' is used in conservation and geology literature to describe different weathering features which are however the results of similar mechanisms, namely the dissolution and re-crystallization of gypsum on the surface or subsurface of its main body.

In conservation literature the general term 'crust' is defined as a 'firmly adhesive deposit on stone surface' (Fitzner *et al.* 1985). Gypsum crusts commonly occur on architectural gypsum surfaces, as well as at the surface of gypsum outcrops. However, the most widely known and extensively studied gypsum crusts are those that accumulate on marble, limestone or other calcareous stone surfaces that are protected from direct washing by rain, in polluted urban environments. There is a long list of references on black gypsum crusts in the proceeding of all international conferences and meetings that focus on stone deterioration and conservation, but make no reference on the formation of crust on gypsum rocks (i.e. Skoulikidis *et al.* 1976, 1981, 1984, McGee 1991, Nord 1992, Moropoulou *et al.* 1998, Böke *et al.* 1999 etc.).

Arnold and Kueng (1985), provide quite a clear and coherent description of these crusts using the term 'cauliflower-like' crusts: "the crust consists of gypsum crystals in the habit of lenticular tablets with a cleavage perpendicular to the tablets.....the tablets are intergrown as rosette-like aggregates, similar to the well known desert roses" (Fig.7.60).

Experimental work and observations of Arnold and Zehnder (1985) have shown that the condition for the formation of a crust instead of efflorescence is the rich supply of salt solution, which means that the body of the rock should be humid or wet. They also conclude that more soluble salts accumulate thicker crusts because their saturated solution contains more solute.

Gypsum is a special case of rock that is in fact a hydrous salt itself capable of dissolving and producing such solutions without the presence of other salts in the atmosphere or in the ground water. It re-crystallizes in a different crystal habit that is easily distinguished from by the original body of the rock due to its different texture. Carbonates and clays from surface depositions (dirt) are often cemented into the secondary gypsum matrix that forms the crusts (Fig.7.61-7.65).

Crusts of this kind occur in all gypsum outcrops and at several gypsum blocks mainly on vertical surfaces that are not directly washed off by rain water. They also appear on gypsum surfaces in restored and sheltered areas but to a lesser extent and in a smaller scale. The crusts are especially thick in the transition zones between sheltered and rain exposed areas, called accumulation zones, which get enough supply of solution without being leached out (Arnold and Kueng 1985).

This effect can be seen on various ashlar blocks at Knossos and at the large massive selenite jambs at the unsheltered part of the West Magazines. The predominant weathering form on the upper part is the dissolution Karren forms, which start from the top and extend on the vertical side for several decimetres. The cauliflower crust accumulates at a zone immediately after the end of the Karren (Fig.7.66a-b). In archaeological context 'cauliflower crusts' appear mostly on massive selenite as this is the main variety that is found in an outdoor environment. However, observation of the weathering forms that occur on gypsum surfaces at the outcrops showed that the same crusts occur in all different varieties given that the exposure of the stone favours the establishment of accumulation zones (Fig.7.66a-b).

A limited number of samples of crusts were taken from selected areas representative of all different microclimates (outdoor, sheltered and restored). Samples were studied by means of Polarised Light Microscopy (PLM), Scanning Electron Microscopy (SEM) and X-Ray Diffraction, in order to verify their origin and to investigate the role of other soluble salts in the development of the crusts.

No other salts were detected by any of the above methods, but the secondary texture of the crusts is clearly observed in thin section under the petrographic microscope (Fig.7.64-7.65) while compositional variations between the secondary crust and the original rock were also detected under the SEM (Fig.7.68-7.70). The original body of the sample consists of Ca and S only, while in the secondary crust layer are detected Ca, Al, Si, Mg and Fe, elements that are characteristic of surface depositions such as soil dust and various other particles carried by the wind onto the surface of the rock. Some chlorides seem to have also penetrated in to the main body of the rock, which also probably contribute to gypsum weathering either by their dissolution and crystallisation or by enhancing the dissolution of the rock, but not in significant quantity (Fig.7.68-7.69).

In the geology literature the term 'weathering crust' refers to geometric and volumetric alteration of gypsum deposits. Macaluco and Sauro (1996, 1998) have studied the development of 'weathering crusts' or morphostructures on the Missinian outcrops of

Sicily which are explained as the result of dissolution and precipitation, processes that allow the re-crystallization of gypsum below the surface (Fig.7.71).

The climatic regime of Sicily is quite similar to that of Crete with an average annual precipitation of 650mm and temperatures ranging from 0°C in the winter to 45°C in the summer. The seasonal fluctuations in the water supply and temperature force dissolution and re-crystallization of gypsum. Rain water dissolves gypsum surface and some of the solution penetrates into the pores and the fractures of the rock. The solution eventually reaches saturation on the surface or below the surface and continues to penetrate into the pores and fissures. During the dry summer months the solution looses water, becomes over-saturated and moves towards the surface. Precipitation of gypsum from the saturated solution can take place on the surface, in which case the crusts that are described by Arnold and Kueng (1985) are formed, or below the surface in which case gypsum crystals are formed in the fissures and the voids of the rock. According to Macaluco and Sauro (1998), this is a mechanism of mass transfer from the outer surface towards the inner body of the rock that results in the increase of volume in the outer zone of the rock and a consequent increase in pressure. Macroscopically it is observed as expansion or swelling of the main body of the rock. The mechanism is schematically shown and explained in (Fig.7.71).

These observations refer mainly to large scale phenomena, such as 'gypsum bubbles' or 'tumulus' and 'polygon forms' or 'polygonal fissures' that develop to a scale of few decimetres up to 15m. Nevertheless, the same processes take place in small scale as well (Fig.7.72-7.75).

Other factors such as the transfer of other material in the pores and the fractures of the rock (i.e. clays or carbonates), increase of porosity due to tensional relaxation of the inner zones as the solution moves toward the surface during dry seasons, plastic deformation associated with the rearrangement of the crystals, transformation of gypsum to hemihydrate and vice versa and combinations of any of these processes also contribute to the formation of gypsum crust as defined by Macaluco and Sauro.

These processes can take place as seasonal, but also as single cycles, i.e. during single rainfall events followed by dryness that occur in the spring, autumn or more rarely in the summer. Even smaller scale events such as condensation during early mornings and late evenings and evaporation during noon can initiate similar mechanisms. The single small scale events usually affect thin surface layers and can explain the appearance of small scale 'tumulus' and 'polygons' on architectural gypsum The 'polygon fissures' are independent of the stone structure and occur on both fine and coarse grained architectural gypsum that is exposed to outdoors environment. They occur on both fine and coarse crystalline varieties and can be classified within the weathering form that is described in the next paragraph (Fig.7.74-7.76).

7.3.1.5 Fissures independent of stone structure

Fissures that are not dependent on the structural characteristics of the stone such as bedding strata, cleavage, etc. (Fitzner *et al.* 1995: 51, 70-71) are caused mainly by mechanical stresses or volumetric changes during dehydration-hydration and/or dissolution-crystallisation cycles. Such fissures occur in all kinds of gypsum and in almost all kinds of architectural functions i.e. ashlar blocks, floor slabs, dadoes, staircase treads etc (Fig.7.74-7.76a-f).

The severe cracking of the gypsum ashlar blocks and orthostates at Knossos that have been burnt at least once during the several destruction phases of the building can be mainly attributed partly to the volumetric changes due to dehydration–hydration cycles that are followed by thermal expansion and contraction and partly to the "weathering crust" mechanism that was described in paragraph 7.3.1.4.

Gypsum shrinks during dehydration and swells during hydration. Conversion of gypsum to hemihydrate is followed by 15.68% reduction of weight and 34.37% reduction of volume. After further dehydration into anhydrite, the reduction in weight reaches 20.9% and the reduction in volume reaches 37.59%. Conversion of hemihydrate to gypsum is followed by 18.3% increase in weight and 52.3% increase in volume while hydration of anhydrite results in a 26.4% increase of its weigh and increase of volume to the extent of 60% (Schreiber 1978, Pechorkin 1983, Karni 1995).

It is obvious that the major fluctuation in volume during dehydration-hydration cycles occurs during the first stage of dehydration of gypsum to hemihydrate and vice versa. It is possible that these volumetric changes are responsible for the fissures that are formed along the crystal boundaries and which are later enhanced by dissolution and secondary crystallisation of gypsum with soil, sand and other environmental depositions. Sample SC31 from one of the gypsum lining of the fifth cist in magazine XII (Knossos) clearly represents the characteristic effects of dehydration, crystallisation of secondary gypsum with foreign grains (dirt) in the thermally induced fissures (Fig.7.77) As already discussed in paragraph 6.1.2, the transformation of gypsum to hemihydrate also results in a large reduction of mechanical strength. The weakening of the dehydrated rock is explained as a result of the increased pore fluid pressure during dehydration which results in the lowering of the confining pressure and the consequent reduction of the cohesive strength of the material. Similar reductions are observed in the compression and shear wave velocities as well as the elasticity of the rock. Thus, the mechanical loads that have been superimposed onto some of the piers or ashlar blocks by the reconstruction of the buildings with modern materials, probably cannot be afforded by the pseudomorphosed blocks, thus some of the fissures may have developed or have been enhanced due to these stresses (Fig.7.76a-b)

However, polygonal fissuring occurs also on rocks that have not been affected by fire and are not subjected to mechanical stresses and therefore it seems that the 'weathering crust' mechanism plays the most important role on the development of these features.

7.3.1.6 Fissures dependent on stone structure

Individual fissures or system of fissures which are dependent on the structural characteristics of the stone such as bedding, laminations, crystal outline, and banding are apparent on all varieties of gypsum rocks and in all kinds of environment (Fig.7.78-6.79).

The most characteristic are the fissures that are formed in the inter-crystal boundaries as a result of dissolution of the inter-crystal matrix and of the crystals themselves. Such fissures eventually develop to granular disintegration into rudite (Fig.7.80)

7.3.1.7 Crumbling

Crumbling is defined as the detachment of larger and compact parts of the stone (Fitzner et al 1995: 49, 64-65). Detachment of large parts of selenite blocks occurs after severe cracking and deformation of the stone due to volumetric changes. As already mentioned above, change in volume can occur through dissolution and crystallisation processes ('weathering crust' mechanism) that have been described by Macaluso and Sauro (1996, 1998), through dehydration – hydration cycles caused by fire during the destruction of the building or mechanical stresses i.e. mechanical loads from concrete restorations superimposed on the original gypsum structure. It occurs on various selenite blocks at Knossos (Fig.7.81a-c), in fewer at Phaistos and Agia Triada, and on just a couple of blocks at Pyrgos and Megaron Nirou. Crumbling may show a transitional form to contour scaling i.e.detachment of large platy stone elements (Fig.7.53) (Fitzner *et al.* 1995: 68-69).

7.3.1.8 Efflorescence and sub-florescence

Efflorescences and subflorescences are defined as the poorly adhered salt aggregates on the stone surface and below the stone surface respectively (Fitzner *et al.* 1985). Gypsum efflorescences and subflorescences occur exclusively in sheltered and restored areas of the examined sites. They mostly appear in areas where fissures or structural discontinuities, i.e. between laminations layers, and in the zone between wet and dry part of the stone which is actually the zone where the rising damp evaporates (Fig.7.82a-b).

Zehder (1993) discusses the development of gypsum efflorescences in veils and powdery aggregates in the upper zone of rising damp on masonry and wall paintings regardless of the climatic conditions. He further argues that due to the 'low solubility' of gypsum desalination methods are not efficient for its removal and that gypsum crystallizes even after wall drying methods. It should be noted here that while geologists usually refer to 'high solubility' of gypsum when examined as a rock, conservation scientists refer to 'low solubility' of gypsum when examined as a salt, which is a contradiction that often causes confusion.

Arnold and Kueng (1985) explain the appearance of pulverulent or powdery efflorescences as a result of dehydration of salts that have first crystallised in hydrated forms. Efflorescence is by definition the loss of water from the chemical structure of a mineral in dry or hot areas which causes the mineral to form a white powder on its surface, and decreases its transparency.

However, examination of powder samples collected from such spots, by means or X-Ray Diffraction, showed that only the hydrated form calcium sulphate (gypsum) is present on gypsum surfaces. This suggests that the efflorescences are formed after dissolution and re-crystallisation mostly of the rock itself, which is the mechanism that is responsible for most gypsum weathering forms, and not by dehydration of crystallised gypsum.

During this study only a few samples were collected from the most prominent efflorescence and subflorescence spots that occur in the restored areas (the Throne Room and the Hall of Colonnades at Knossos as well as Room 4 in Agia Triada) and therefore a more systematic survey and sampling of these phenomena is needed in order to be able to understand the mechanism of their formation. A more careful and systematic selection of samples, as well as special measures for the preservation of the samples, are needed in order to be able to study the influence of other salts apart form gypsum itself in the development of efflorescences and subflorescences.

7.3.1.9. Exfoliation

According to the same classification scheme, the term exfoliation refers to the detachment of stone sheets or plates, following the stone structure as well as the stone surface, and occurs at building stones of which a structural feature is oriented parallel to the stone surface.

Exfoliation occurs on the laminated and the nodular and lenticular varieties, whether affected by fire or not and mostly on wall dadoes where the displayed surface of the rock is parallel to the lamination layers. Exfoliation occurs due to the expansion and/or dissolution of the clay and/or carbonate laminations (Fig.7.83-7.84). Further, the development of subflorescences in between the lamination layers enhances the exfoliation of the rock (Fig.7.85). Exfoliations have been observed mainly in the restored areas of Knossos and especially on the wall dadoes at the Hall of Colonnades and the North Lustral Basin

7.3.1.10 Microbiological colonization or Biodeterioration

Biological growths occur mainly in outdoor environments and are favoured during winter months, and especially from January to March which are the months with the highest values of precipitation and relative humidity. Macroscopic observation of the predominant biological crusts, of gypsum surfaces at Knossos and the outcrops, suggests that biological deterioration is a secondary process that develops in soil, which already exists in the cracks and the fissures of the stone and in the joins of consolidation mortars (Fig.7.86a), or in the dissolution levels (Fig.7.86b). It is more intense at the lower parts of blocks, which are sitting directly on soil and maintain moisture for a longer time (Fig.7.87a). The cauliflower crusts that were described in paragraph 6.3.1.4 are all covered by microbiological crust during winter, having a green appearance (Fig.7.87b). In some cases however, biological colonisation was visible under the cauliflower crusts and at the backside of large loose crystals, which were detached from the main body of the rock, grown directly on the crystal surface and penetrating into the crystal planes (Fig.7.88-.7.89).

There are few examples where biological crusts have played a protective role for their substrate, but in most cases the biological factor acts as a catalyst to the majority of the deterioration processes. On the outdoor gypsum blocks there are clear examples where mechanical damage is caused entirely or partly by biological deterioration, such as the fracturing, granular disintegration and detachment of larger fragments. Enhancement of the cracks due to the expansion of the biological growths often results in complete detachment of fragments from cracked areas of blocks, starting from the corners and edges.

A secondary effect is the aesthetic one. It has been demonstrated in the previous chapters that the gypsum orthostates of the West and South Façade, of Knossos Palace as well as those of the surrounding buildings, are integral parts of the buildings intended to impress the visitor. The alteration of their surface by the extended crusts results in loss of the aesthetic qualities, which Minoans intended to project, and obscures the observation of stylistic characteristics such as the use of different varieties of gypsum arranged in decorative schemes. The overall evaluation of the biological factor brings it in a high priority as regards the preservation of the outdoors elements, while in the indoor or sheltered environments appears to be less important. In sheltered or restored areas, biological growth occurs under loose scales of the floor slabs or under chips and flakes of the gypsum dadoes, which have already been loosened by the action of salt sub-fluoresces.

Some discoloration or staining of interior gypsum dado surfaces may also have a biological origin, but their examination would require sampling from solid dado surfaces which has not been intended in this study as such a permit has not been issued. Besides, the study of all the different biological species, which grow under the various microclimates within the broader context of the site, would require extensive sampling of various crusts in order to isolate and identify the species, which is not within the scopes of the present study. The identification of the genus of the different species, which is essential in order to understand their interaction with stone surface, should be the subject of a separate study. Such a study should be carried out by biologists with special training on stone bio-deterioration in conjunction with the site conservators, aiming at the establishment of protective measures for the prevention of bio-deterioration.

However, a preliminary examination of the most distinctive and extensive bio-crusts was attempted in order to define the nature of the biological organisms present on gypsum and to investigate the potential of damage due to bio-deterioration. The bio-crusts, which develop mainly on the outdoors gypsum blocks at Knossos palace, were sampled for first time in January 1997 and were studied by Dr. Adriane Pantazidou at the Department of Ecology and Systematics, University of Athens.

In her first preliminary examination A. Pandazidou recognised species of lichens, algae, mosses, (Vria), cyanofyceae as well as roots of higher plants. The samples however were not preserved very well and therefore no further observations could be made. A second sample series was taken in February 1999, in order to identify the nature of the micro-organisms, which comprise the biological crust and to verify their impact on gypsum deterioration. The second series consisted of 5 samples, 4 of which were taken from the same gypsum orthostate of the West Façade of Knossos which corresponds to Magazine VI. The main criterion for the choice of sampling location was the presence of extensive biological crusts on its surface, which included the most representative species according to macroscopic observations. Samples 1-4 are all facing east. The sampling location has the advantage of being monitored, since the RH and T loggers for the study of the outdoor environmental parameters were installed next to it. Sample 5 was taken from one of the polygonal fissures of a selenite block at the south of the West Court (Fig.7.90).

Description of samples

Sample 1: light green part of the biological crust appearing mostly on vertical surfaces. The sample was taken from the inner side of the orthostate. The sampling location is 28cm above the soil that fills the gap in between the two orthostates. The total height of the orthostates is 1.05 cm.

Sample 2: dark green part of the biological crust. The sample was taken from the same orthostate as sample 1, 12cm above the soil.

Sample 3: yellowish part of the crust. Sample taken from the same orthostate 25cm above the soil level.

Sample 4: this sample consists of loose crystals from the same orthostate, where biological growths are developed on their inner surface, and not on the exposed outer surface.

Sample 5: the sample mainly consists of soil from the cracks of an abandoned block, south of the West Court. Although the sample does not seem to be rich in biological matter, it presents interest as regards the effect of the biological growths to the enlargement of the cracks. The sample location is 60cm above the soil level and has a south west orientation.

Identification of species

The samples were delivered to the Dr Pantazidou within three days after sampling and in a good state of preservation. The following observations were made after study under stereoscopic microscope:

Sample 1: the first sample consists of lichens, which grow either directly on the gypsum crystals, or in the soil sitting in the cracks and in between the crystal boundaries. Along with the lichens there are various algae, grown directly on the gypsum surface or in the crystal planes, indicated by the light blue-green colouring of the crystals. Several *protonimata* (hyphae) of lichens, are visible in the soil and around detached crystals of the material, which are mixed in it. Some mosses are also present in the sample. The lichens are associated with various species of fungi and algae.

Sample 2: the second sample contains mainly of mosses some of which are dry. They appear like small brown bushes and grow together with other micro-organisms on a layer of soil. On the back surface of the crust there are detached and broken gypsum crystals mixed with soil. Several *protonimata* are visible, some of which are found directly on the loose gypsum crystals, suggesting that the biological crust, could develop even without the presence of soil. It is most definite however, that the soil offers a good media for the establishment of biological colonisation.

Sample 3: the reddish-yellow crust consists of lichens. The red parts of the crust are the *apothikia* of the lichens. Several different species of lichens, indicated by different colours seem to develop directly on the crystals. The sample contains less soil than the previous ones, and the biological crust is in general a more direct one.

Sample 4:this sample consist of various kinds of *cyanofyceae* that are difficult to identify and which are developing within the crystal planes, probably along with other kinds. Different colours indicate the different kinds of micro-organisms.

Sample 5: the last sample consists mainly of algae, which are again directly grown on small crystal fragments and in the soil which is filling the crack, a well as mosses (vria), which are grown on top as a second layer.

According to the above study, the main species that grow on gypsum in the outdoor environment of Knossos are algae, lichens, moss and higher plants, which are most definitely accompanied by several species of fungi and bacteria. They clearly cause serious mechanical damage as they can detach large crystals or fragments. After the microscopic observation of the samples it became apparent that the lichens and the algae can grow directly or indirectly on the material while the moss and the higher plans require a layer of soil.

The observation of thin section of sample SC45 (Fig.7.88) under stereo-microscope and polarised light microscopy (PLM), showed clearly the presence of organic material in between the crystals to a depth of 1,5cm below the surface, which documents the influence of biological factor in the process of granular disintegration (Fig.7.89). Bio-chemical deterioration caused by the metabolic processes and the products of biological organisms, probably takes place along with physical/mechanical deterioration. Jones and Wilson (1985) have extensively discussed the chemical activity of lichens and conclude that their weathering effects are related to the excretion of various chelating organic agents. Lichen acids and oxalic acid are often involved in the weathering process, causing pitting and honeycomb effect. Organic acids also attack the inter-crystal cementing media, resulting in granular disintegration.

6.3.1.11 Colonisation of higher plants

Colonisation of higher plants is evident on gypsum that is exposed in an outdoor environment. Accumulation of dust and soil within dissolution levels on gypsum blocks creates a suitable ground for the colonisation of higher plants that resemble 'Japannese gardens' (Fig.7.91). Higher plants are also growing in dissolution runnels, in joins between blocks and between gypsum and restoration mortars, and in cracks and fissures (Fig.7.92-6.94).

Roots of higher plants were also identified by Dr. Pantazidou in the samples that were described in the previous paragraph. Penetration of the roots into pre-existing fissures of the stone and the inter-crystal boundaries introduce mechanical stresses which result in the loosening and eventually detachment of crystals or fragments of the rock. The overall action of higher plants is similar to that of microbiological colonisation but the mechanical stresses involved are greater and there and the weathering effect more intense.

7.3.1.12 Coloration

According to the Fitzner et.al (1995) classification scheme, coloration is the chromatic alteration of the stone due to weathering of minerals or the accumulation of colouring matter. The colour of the gypsum rocks, especially the pinkish-red, may be enhanced by burning due to oxidation of iron oxide inclusions. Such coloration is evident at the surface of laminated gypsum at Phaistos and Agia Triada. The colour is mostly enhanced on the upper layer and in some instances, where this layer has dissolved away (after the exposure of the material in outdoor environment), the original colour of the rocks, which is quite lighter, is revealed (Fig.7.95).

Black staining of the surface, due to fire, has also been observed mainly in areas where organic material was present, such as the west magazines at the Palace of Knossos and the storerooms of Phaistos and Agia Triada, as a well as in closed spaces with poor ventilation such as the 'Dog's Leg Corridor at Knossos. It is mostly attributed to the combustion of oil or other organic products. On some floor slabs, the black stains show a pattern that indicates the combustion of some liquid on the surface (Fig.7.96).

Experimental firing of gypsum samples partly impregnated in olive oil versus clean ones showed that the oil saturated area of the samples turned black very soon after the inflammation of the oil. Inflammation continued even when the samples were removed from the fire, until almost all of the oil that penetrated the sample was totally burnt. The stain extended up to the depth of the oil penetrated part of the sample (Fig.7.97-7.98). Therefore it seems very likely that the black gypsum, found at Agia Triada as well as most of the staining at the West Magazines at Knossos and Magazine 33 at Phaistos, is the result of combustion of organic matter that was stored in them and most probably of olive oil that was the main product of Minoan farming.

Petrographic study of samples which show the transition line between the white and the black stained part of the stone has shown that the dehydration features are more intense in the black areas of the sample (Fig.7.99).

6.3.1.13 Deformation

This term refers to bending of thin stone slabs due to plastic deformation (Fitzner et al 1985). It occurs often in marble slabs and is also known as bowing of marble. Bowing of marble is quite a common feature, yet not fully understood. Amongst the factors that have been considered to contribute to the deformation of marble is the anisotropy of the crystals (different expansion- contraction at different planes), the freeze-thaw cycles, and residual stresses (Koch 2004). The deformation of gypsum however has never been examined and therefore within the limits of this study is not possible to investigate the mechanisms that are involved in development of this weathering form. Some interesting observations though, have been made.

Deformation of thin gypsum slabs (5-7cm thick) occurs mainly at the Residential Quarter of Phaistos (Fig.7.100). These are modern slabs consisting mainly of chaotic gypsum that were used by Levi in the mid fifties, to replace the original fragmentary floor slabs. Some cases of deformation have also been observed on modern gypsum slabs at the Long Gallery of the West Magazines of Knossos, placed there during the restorations of N. Platon that were carried out at about the same period (mid fifties/early sixties).

Deformations occur sporadically on the original gypsum slabs. The most representative examples are the burnt wall dadoes in the Dog's Leg Corridor and the Room of the Plaster Couch at Knossos, and the dado of the Light Well at Pyrgos, which are all burnt and stained black (Fig.7.100). In contrast to the deformation of the marble slabs that indicate expansion with the corners bending inwards, the deformation of the gypsum slabs usually indicate contraction with the corners usually bending upwards. The few cases where bending indicates expansion of the rock could be explained as the result of dissolution and crystallisation of secondary gypsum in the inter-crystal space acting in mechanism similar to the 'weathering crust' that has been proposed by Macaluso and Sauro (1996) for the expansion and the development of polygonal fissures on more bulky gypsum elements.

Considering that deformation occurs mainly on modern slabs and only on few burnt massive or banded selenite Minoan wall dadoes, It could be assumed that deformation is also related to the crystal size, the cutting direction of the slabs and their exposure to high temperatures induced either by fire or by the direct sun light. The Minoan masons were usually selecting material with the least inconsistencies of texture and did not use slabs in outdoor environment, which could expose them to wetting - drying or dissolution – crystallisation cycles. However, a further examination and experimental study of the development of bending, with respect to crystal texture and size, is needed before we can make any suggestions as regards its genetic aspect.

7.4 Distribution of weathering forms in the examined buildings

The palace of Knossos offers the ideal context for the study of gypsum weathering, since all different varieties can be found in both sheltered and outdoors microenvironment. At Megaron Nirou on the other hand, the diversity of gypsum varieties that are used in a relatively small building allows the comparative study of the weathering forms which occur in different varieties under the same exposure (excavated in 1919, exposed to rain until 1972 and then covered with an open light shelter). For the weathering of laminated gypsum, Phaistos and Agia Triada obviously offer the best study cases, including both sheltered and unsheltered areas. At Pyrgos, the material is quite well preserved probably due to its shorter exposure to the environment (excavated only 30 years ago) and there are no additional weathering forms other that those that were observed at Knossos. Besides, the most important gypsum structures, such as the bench and the grand staircase have been covered with soil and field stones, a temporary measure against the action of rain water.

As demonstrated up to now, the weathering forms that occur on Minoan gypsum are mostly attributed to dissolution-crystallisation and dehydration-hydration cycles combined with biodeterioration and mechanical damage caused by mechanical loads and the roots of higher plants. The weathering forms that prevail differ according to the variety and the micro-environment to which the rock is exposed. In Table 7.3 are classified the major weathering forms that occur on each variety and the environment in which they develop.

Mechanical damage of the wall and floor slabs was probably initiated during the destruction of the building i.e. collapse of roofs, columns or walls and is evident in all sites and on all varieties of gypsum. Furthermore, cracking and perhaps deformation of the material has developed due to mechanical stresses caused by thermal expansion or contraction during the transformation of gypsum to hemihydrate and vice versa and the subsequent reduction of its mechanical properties and/or by dissolution-crystallisation cycles.

The distinctive micro-relief of dissolution rills and runnels, starting from the top and developing downwards, as well as mini-craters on most horizontal surfaces, prevail on fine grained varieties or pseudomorphosed selenites that are exposed to an outdoor environment. The coarse crystalline varieties (unaffected selenites) on the other hand, that are exposed to the same environment and for the same length of time show mostly granular disintegration and crumbling. This is clearly observed on several partly burnt blocks of gypsum where the original texture exhibits completely different weathering features from the burnt part. Balatino rocks show *Karren* features, 'weathering crust' of 'polygon forms' as well as fissures depended on the laminated structure and exfoliation in the form of detachment of scales between lamination layers.

The gypsum elements, that are protected from rain either by light shelters or by concrete restorations, are far better preserved. Efflorescences, subflorescences and exfoliation are the main weathering forms that occur in sheltered environment when there are no leaks of water through cracks or holes in the roofing structure causing accelerated concentrated dissolution as seen in the case of Megaron Nirou and West Magazines.

CHAPTER 8

CONCLUSIONS

A series of objectives were laid down in the beginning of this research. The first objective was the identification of the archaeological and social significance of gypsum, that implied a series of questions concerning the provenance, production, distribution and consumption of Minoan gypsum. The second objective of this work was the diagnosis and evaluation of the major weathering factors that affect gypsum decay and the classification of the predominant weathering forms with respect to the physical and chemical characteristics of the stone, the architectural function and the environmental parameters that its exposed to.

In the course of this study some of these questions were answered and some new were raised. As regards the archaeological and social significance of gypsum, surveying and sampling of the outcrops, combined with analysis of data presented from the Neopalatial buildings of Crete with focus on five buildings, Knossos palace, Megaron Nirou, Phaistos palace, the villa of Agia Triada and the country house of Pyrgos, where gypsum was extensively used in architecture, has provided important information concerning the provenance, the technology of production, the function of gypsum architectural members, the total volume used in the building, preferences in varieties, and stylistic variations or similarities between sites.

The survey of gypsum outcrops showed that gypsum rocks are available in a number of locations along the entire island, some of them relatively easy to access and to extract and with a variety of morphological characteristics per outcrop. The petrographic study of samples from the examined buildings allowed the detailed classification of the varieties that were available to the Minoan masons on one hand and on the other hand, of those that were used in the buildings for structural or ornamental architectural features. Provided that the Minoan architectural gypsum elements have often been burnt and undergone alteration of their original structure, are often covered with surface encrustations or have in general suffered severe weathering, the only secure method of identifying the variety is the microscopic observation of the crystal texture. Therefore, the identification and classification of the varieties of Minoan gypsum, was possible only after comparative microscopic study of samples from both the sites and the outcrops combined with careful *in situ* macroscopic observations. Once the classification was completed, the macro-crystalline and crystalline varieties, in particular, could be identified with the naked eye, even when burnt and weathered.

There are two major groups of gypsum outcrops on Crete: the Permian deposits, that are distributed in east and west Crete and the Neogene deposits of the Late Miocene (Messinian), distributed in the central and the south coast of east Crete.

The Permian gypsum shows diagenetic textures and has probably derived from the hydration of anhydrite. It is usually microcrystalline and white in colour, sometimes with a grey/bluish tinge and often veined. The main deposits of Permian gypsum are those of Stomio, Sougia, Rodovani, Elafonisi, Palea Roumata in the west, and Altsi, Chrysokamino, Roukaka (Chrysopigi), Sfaka, and Cavo Sidero in the east, of which the last two have been fully exploited and only traces remain visible at present. Although Permian gypsum can provide attractive surfaces, suitable for decorative purposes and outcrops in substantial quantities near major Neopalatial sites, it was not exploited at Minoan times. Although Minoan quarrying technology was sufficient enough to allow the extraction of suitable stone from the lower levels of the outcrops, we can not exclude the possibility that the Permian sources were disregarded by Minoans because of the fractured appearance of the upper layers of the deposits, due to the expansion that is associated with the alteration of anhydrite to gypsum.

The Neogene (Messinian) gypsum on the other hand, which was lavishly used in palatial Minoan architecture, shows primary textures, both macro-crystalline and microcrystalline with a great variety in morphology. The macrocrystalline gypsum, which is organized in beds with centimetric crystals, is known as selenite, a spectacular variety of primary gypsum consisting of large translucent crystals that form very attractive and highly reflective surfaces. Three types of selenite were identified in the examined buildings: massive, banded and nodular and lenticular.

The first type, massive selenite, occurs in thick beds made of orderly rows of large, mostly vertically standing crystals, from few centimetres up to a few decimetres long. Due to the large size of the crystals the sparkling effect on the reflective surfaces of this variety is the most impressive one. It was used for both exterior and interior architectural elements and mainly for structural purposes at Knossos, Megaron Nirou, Pyrgos and to a lesser extent at Galatas, where it is the only variety that was used. Massive selenite is outcropping near Knossos at Gypsades, Tsangaraki, Foinikia, Malades, near Pyrgos at Myrtos and Tertsa, and at Myrtia in the Pediada region not very far from Galatas. In the latter only massive selenite occurs.

The second type, banded selenite consists of smaller crystals (0.5-2cm) organized in a few centimetre thick layers which are marked by thin and faint laminations parallel to the bedding. It is the main variety that is used at Pyrgos and to a lesser extent at Knossos and Megaron Nirou for both structural and ornamental architectural features. It occurs in almost all outcrops south west of Knossos and at Myrtos.

The third type of macrocrystalline gypsum is the nodular and lenticular selenite, which is composed of centimetric nodular and lenticular aggregates of clear translucent gypsum crystals included in laminated fine-grained gypsum layers and oriented perpendicular to them. The nodules and the lenses of the clear crystals are showing wavy veining when the stone is cut in a direction parallel to the laminations, or parallel veining when cut vertically. Due to its laminated structure this variety can be easily separated into slabs, either by cutting or splitting the rock along the laminations. It has been almost exclusively used in the interiors of the palace of Knossos and in Megaron Nirou mainly for ornamental purposes. . It occurs in the gypsum deposits of Myrtos in the east, and in central Crete at the outcrops of Gypsades, Foinikia, Tsangaraki, Malades, Agia Barbara and Sarchos.

The primary microcrystalline gypsum, of Neogene age, is a fine-grained variety showing thin laminae of carbonate and/or argillaceous material, known as balatino. The concentration of different minerals into the laminae produces a large variety of colours from light green-grey to brown-orange or pink-red. When cut in a direction parallel to the laminations it displays a highly decorative surface with wavy veining while in vertical section it shows mostly parallel veining. As the nodular and lenticular selenite this variety can be easily separated into centimetric- to decimetric thick slabs. Balatino is the only variety that was used at Phaistos and Agia Triada for both structural and ornamental purposes and outcrops mainly at Agia Triada, Ambelouzos, Roufas and Plouti in the Mesara and to a lesser extent at Foinikia, Tsangaraki, and Sarchos to the south of Heraklion.

One more kind of primary Neogene gypsum, is the chaotic selenite which comprises of all the above primary rocks embedded in a chaotic gypsum matrix found in blocks of limited size. This variety was not used by Minoans due to the inconsistency of its texture and the limited scale of the blocks but it was used in the modern restorations, especially for the replacement of the original gypsum floors of Phaistos, therefore once the varieties are classified, the modern slabs can be easily distinguished from the new ones even when they are weathered. Chaotic selenite is outcropping in the Plouti-Moroni area, near Agia Triada and north-west of Agios Silas in the Knossos region.

Furthermore, the study of gypsum samples under the microscope revealed the original texture of the Minoan gypsum rocks, which were due to fire or severe weathering and thus difficult to correlate macroscopically to the lithological facies that can be seen at the outcrops. Transformation of gypsum to hemihydrate (and perhaps in some cases to anhydrite) and vice versa has been attested in a number of samples from the buildings. Macroscopic examination and petrographic study of the so called 'alabaster', frequently referred to, in archaeological publications and by all tour guides, as a distinctive characteristic of the Minoan palace of Knossos, showed that the Minoan alabastrine gypsum was formed by burning or heating of selenite rocks and not by diagenetic processes as the true alabaster. Some of the dehydration textures that were observed under the microscope can be of diagenetic origin but such features do not occur at the outcrops and therefore it is certain that the secondary textures that have been identified in many of the examined samples were produced by post-quarrying processes and that the varieties that were quarried and placed in the buildings were originally primary ones.

Therefore it was acknowledged here for the first time that the massive white alabastrine rocks typical of the Knossos Palace are the result of burning or heating of massive or banded selenite rocks. The originally transparent reflective selenite crystals have become opaque and dull resulting in a present macroscopic appearance that is completely different from the original.

Similarly, the wavy laminated, often colourful alabastrine rock that was extensively used in the interiors of Knossos and Megaron Nirou for wall dados and floor slabs, benches, staircases and various other functions, is the product of dehydration and re-hydration of nodular and lenticular selenite. The most brilliant example of this variety of gypsum, in red-orange hues, is found at the first flight of the 'Grand Staircase' where the rock is quite well preserved due to its immediate protection from the rain, despite the fact that for several years it was stepped over by thousands of visitors.

The colours of the laminated and nodular and lenticular varieties have been enhanced due to oxidation of ferrous inclusions, probably during fire. Besides, dehydration features such as pseudomorphs, cannot be macroscopically recognised on fine grained balatino or in the nodules and lenses of nodular and lenticular selenite and therefore the identification of the tow varieties at the sites was often difficult or impossible. In most cases the examination of thin section under the microscope combined with macroscopic observation of the rock on site was necessary in order to distinguish between nodular and lenticular and laminated gypsum.

Unfortunately there are no visible remains of Minoan gypsum quarries preserved to the present and we cannot be sure of the exact provenance of all the above varieties or the quarrying method that was applied for their extraction. We know that the least two Minoan quarries of balatino existed, one at Phaistos and a second at Agia Triada dated by ceramic evidence, but which are not visible at present. At least three different possible quarry locations have been at the Gypsades hill, of which one may have provided the nodular and lenticular gypsum and small amounts of laminated gypsum that is associated with it, and the another two or at least one of them (LC2), have probably provided mostly massive and less banded selenite in substantial quantity and in beds suitable for the extraction of bulky architectural elements, such as the orthostates and the piers that were used in the building projects of the Knossos area..

Most of these varieties can be found in various locations but due to the lack of a comprehensive and detailed geologic record of the Neogene evaporites of Crete we can not be certain about the suitability of all these occurrences for exploitation. A study on the stratigraphy and morphology of these deposits would contribute to a better understanding of the bedding characteristics and it would perhaps narrow down the areas in which the varieties of Minoan gypsum exist in an exploitable form and bulk for architectural purposes. Nonetheless, it has become clear that gypsum from the area of Knossos was used at Amnissos, Megaron Nirou, Pseira, Zakros, Palaikastro and perhaps at Archanes, while Phaistos, Agia Triada, Pyrgos and Galatas used gypsum from the quarries of Agia Triada and Phaistos, and the outcrops of Myrtos and Myrtia respectively, which are located in their immediate vicinity. Thus, exploitation of gypsum remains local, with main consumers the large palatial sites of Knossos and Phaistos, the 'elite' buildings of Agia Triada, Megaron Nirou, and probably the building in Tourkogeitonia at Archanes, which have close cultural and political links with them, as well as Pyrgos, that although the furthest site with no apparent geographical relation to the others, shares quite a few common architectural features with the palatial centres. Galatas and the harbour towns of Amnisos, Zakros, Pseira, and Palaikastro used gypsum to a lesser extent, while at Kommos there is only a small slab of uncertain function and context, which cannot be classified as architectural gypsum.

Not surprisingly, these sites are all distributed in the central and east Crete and most of their gypsum fittings date to the New Palace Period, that is characterised by intense building activity is evident through out the island. Driessen (1991) has already pointed out the concentration of palatial architectural features, of which gypsum is one, in the Knossos region and the south and east coast of the island, but it is rather interesting that architectural gypsum is not only completely absent from the sites of west Crete, but also from many major sites with palatial architectural characteristics in the central and east Crete such as Mallia, Gournia, Petras, Mochlos, Tylissos or Vathypetro, despite the fact that some of them had easy access to the Permian sources of gypsum or had harbours and therefore gypsum could be easily transferred from the Neogene sources of central Crete by boat. The restricted distribution of gypsum at the sites, despite its abundance in nature, indicates that consumption of the stone is limited within palatial sites and prestigious town or country houses which had maintained close social and political links with Knossos or perhaps were under the complete political control of the Knossian state and that although the basic design and organisation of the palatial buildings of Neopalatial Crete follow the Knossian prototype, not all architectural features of Knossian style or the so called 'School of Knossos' were fully adopted by all other settlements.

Furthermore, within each of the sites gypsum is always concentrated in elite buildings that are the dominant structures of each settlement suggesting that the sources were controlled and that only specific groups of the Minoan society could have access to the quarries or could afford the investment that was required for the extraction and the production of finished architectural gypsum fittings. And even within the individual buildings gypsum is again found in the finest rooms. Further estimation of the surface that gypsum would have originally covered in the most important sectors of these buildings, indicates that the largest part of the interior space area of the rooms was dressed with gypsum.

The execution of the quarrying, shaping, transporting and placement of the stone in the building could only be achieved by an organised production system that included specialised groups or craftsmen who knew how to choose the suitable stone beds and how to extract blocks of the desired size and quality, skilled masons that were in charge of the shaping and dressing of the stone and workmen that were only involved in the lifting and transportation of the stone to the building site. Rough estimations of the labour and the time that was required for the extraction, dressing and placement of the stone in the building indicate that at least four hundrents of workmen would have been working for a minimum of a couple of years for the completion of the works. Such work force could only be provided by the central administration system of the ruling class.

Furthermore, the high level of organisation that was required for the operation of the building projects could again be achieved only within the broader central administration system that was based at the palace. The qualified masons and quarrymen of Knossos probably travelled with their tool kit, to places like Megaron Nirou or Amnissos, in order to execute the building projects as appointed by the ruler or the authority of Knossos with raw material provided from the organised quarries that were probably in continuous operation serving the needs of various building projects around the palace and occasionally providing small quantities of it for projects at further distances. In places were gypsum was available at a local source, i.e. Pyrgos or Galatas, an group of specialists could have arrived on the building site with their tools and would have either executed the entire project or trained the local craftsmen how to cut and carve the stone themselves.

The uniformity of the material used for individual rooms and functions at Knossos and Megaron Nirou, suggest that there was an organised quarry with open works at different beds or different quarries that produced different varieties of the rock. The similarities in size and morphology of several slabs, the regularity of both front and back surfaces and their even thickness, further indicates that the stone probably arrived at the site in large blocks, which were then sliced with a saw into thin slabs. We cannot exclude the possibility that the slabs arrived in stacks already sliced, that were then trimmed down to the required size at the building site.

The quarrying technique and the tools that was used for the extraction of the stone was probably the same as those used for sandstone, however, there are no visible remains of quarried phases at present to confirm this hypothesis. The cutting and shaping of gypsum was also carried out with the same tools and techniques that were used for all other stones. Picks and adzes were used in the quarrying process while chisels, points and punches were mostly used for cutting and shaping the stone. The final shaping of the stone probably took place near or at the building site so that the possibility of damaging the thin slabs or curved details of this quite soft stone over transportation was minimised. An organised workshop, where the stone was finally finished before its placement in the building, must have been established near the building although no archaeological record of it is available. Thin slabs were obtained by cutting larger blocks with mason's saws the only known Minoan type of tool that could be effective in cutting such large and thin slabs. Both toothless and toothed saws could be used for cutting gypsum. Perhaps the toothed saw, although primarily used for wood, would be quite efficient for coarse grained gypsum as well, like the nodular and lenticular and the massive selenite of Knossos. When the slabs were cut they were placed on the wall that was already prepared with a clay mortar.

The establishment of the special character of gypsum as one the most characteristic and exclusive symbols of the Knossian elite is consolidated during the New Palace period. A rather large area of the visible surface of the examined buildings was dressed with gypsum and although large volumes were used for bulky structural elements, the main the function of gypsum in Neopalatial architecture is decorative. It was principally used as an ornamental stone, in the form of thin paving slabs and revetments, which were applied as facing to rubble structures. This very efficient method of creating a luxurious interior space with minimum consumption of valued materials appears for first time in the palaces of Crete and especially in the New Palace Period as a consequence of the increasing demand for decorative stone that is associated with the expansion of the power of the Knossos state in central and east Crete that was expressed through the construction of monumental structures and the use of exclusive, prestige materials as a kind of status markers.

The palace of Knossos offers the ideal context for the study of gypsum weathering, since all different varieties can be found in both sheltered and outdoors microenvironment. At Megaron Nirou on the other hand, the diversity of gypsum varieties that are used in a relatively small building allows the comparative study of the weathering forms which occur in different varieties under the same exposure (excavated in 1919, exposed to rain until 1972 and then covered with an open light shelter). For the weathering of laminated gypsum, Phaistos and Agia Triada obviously offer the best study cases, including both sheltered and unsheltered areas. At Pyrgos, the material is quite well preserved probably due to its shorter exposure to the environment (excavated only 30 years ago) and there are no additional weathering forms other that those that were observed at Knossos. Besides, the most important gypsum structures, such as the bench and the grand staircase have been covered with soil and field stones, a temporary measure against the action of rain water.

As demonstrated, the weathering forms that occur on Minoan gypsum are mostly attributed to dissolution-crystallisation and dehydration-hydration cycles combined with biodeterioration and mechanical damage caused by mechanical loads and the roots of higher plants. The weathering forms that prevail differ according to the variety and the micro-environment to which the rock is exposed. The rather poor state of preservation of the majority of the Minoan gypsum remains can be partly attributed to the alteration of its texture resulted from the fire that followed the destruction of the buildings. It is apparent that the un-burnt parts of the material are far better preserved than those which been subjected to dehydration – rehydration cycles. The careful choice of certain varieties for specific functions and their wise placement in the building suggests that Minoans were aware of the properties of the stone and the effects of rain on the different varieties weathering and therefore protected the fine grained varieties form the rain and exposed in outdoor environment only the coarse grained massive selenite which resisted dissolution remarkably well until it burnt to be transformed into a fine grained gypsum that was not meant to be exposed to the rain and which gradually started to dissolve showing intense karren form on its surface.

The preservation of the gypsum elements, that are protected from rain either by light shelters or by concrete restorations, are far better preserved. Efflorescences, subflorescences and exfoliation are the main weathering forms that occur in sheltered environment when there are no leaks of water through cracks or holes in the roofing structure causing accelerated concentrated dissolution as seen in the case of Megaron

Nirou and West Magazines.

Within the framework of the conservation and preservation of the Minoan Palaces, the protection of architectural gypsum is one of the primary objectives. Although the fundamental principles of gypsum weathering have been outlined in the present research, a more systematic approach to the study of gypsum is needed in order to be able to understand the evolution of its decay, and to develop the appropriate conservation policy, aiming at the effective and long-term preservation of the material.

The archaeological study of gypsum has demonstrated its significance and has shown that its preservation as an integral part of the Minoan architectural design is of vital importance. Undoubtedly, the conservation and protection of its original remains, regardless the present state of its preservation is a more appropriate policy than its replacement by new gypsum that often has different texture and appearance from the original one.

There are always risks when applying conservation treatments since their effectiveness can only be tested by time. We often hear that the previous conservator or restorer was the most destructive factor of deterioration, although he had considered all the possibilities, based on the knowledge that was available to him at the time. Evan's restoration and reconstruction of the Palace of Knossos has long been subject to criticism even by Levi, who 50 years later demolished the majority of the original gypsum floors of the Residential Quarter and the vestibule of the magazines at Phaistos.

However, in recent years the co-operative efforts between scientists and engineers on one hand and curators, archaeologists, and conservators on the other hand has contributed to achieving a better understanding of the conservation problems of stone monuments and in planning possible solutions to them. Besides, multidisciplinary work is guided by a common theory, principles and ethics of conservation and the international recommendations such as the International Charter for the Conservation and Restoration of Monuments and Sites (Venice Charter 1964), the conservation practice of the International Council on Monuments and Sites (ICOMOS 1965, revised in subsequent years by supplementary Charters) or the conventions and recommendations of the Cultural Heritage Division of UNESCO.

For many years in the history of conservation, conserving the stone meant intervention on its surface. In the last years though, the increasing awareness of the principle of minimum intervention has led to increasing emphasis on preventive conservation measures instead of active conservation treatment. Preventive conservation means to control the weathering factors, which favour the evolution of deterioration processes rather than treating the stone itself and seems to be the only effective way of protecting Minoan gypsum in the long term. However, drastic solutions such as the erection of protective shelter over the entire area of the site requires a thoughtful consideration of broader issues other that the preservation of a single building material, such as the impact of the structure in the broader environmental context and the landscape beyond the limits of the site.

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"Gypsum in Minoan Architecture: Exploitation, Utilisation and Weathering of a Prestige Stone"

Vol.II: Illustrations

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Formula	Description
$CaS0_4 \cdot 2H_20$	Gypsum, selenite, alabaster, satin-spar, calcium sulphate dihydrate
$CaS0_4 \cdot 1/2H_2O$.	Hemihydrate, plaster of Paris, bassanite
γ-$CaS0_4$ (metastable).	Soluble anhydrite, dehydrated hemihydrate
β-$CaS0_4$ (stable to 1200°C)	Anhydrite, insoluble anhydrite, dead-burned gypsum
α-$CaS0_4$ (stable above 1200°C)	a-$CaSO_4$

Table 2.1: Terminology for calcium sulphate and its dehydration products

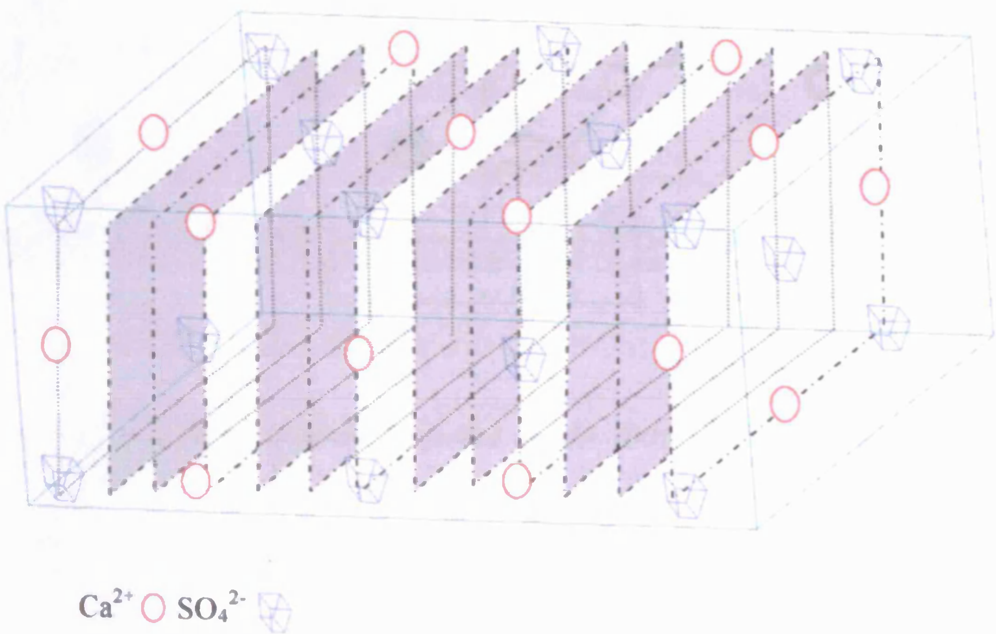


Fig.2.1: gypsum structure schematically shown after Wooster 1936. Water molecules lie in the grey shaded planes that are parallel to the perfect cleavage plane.

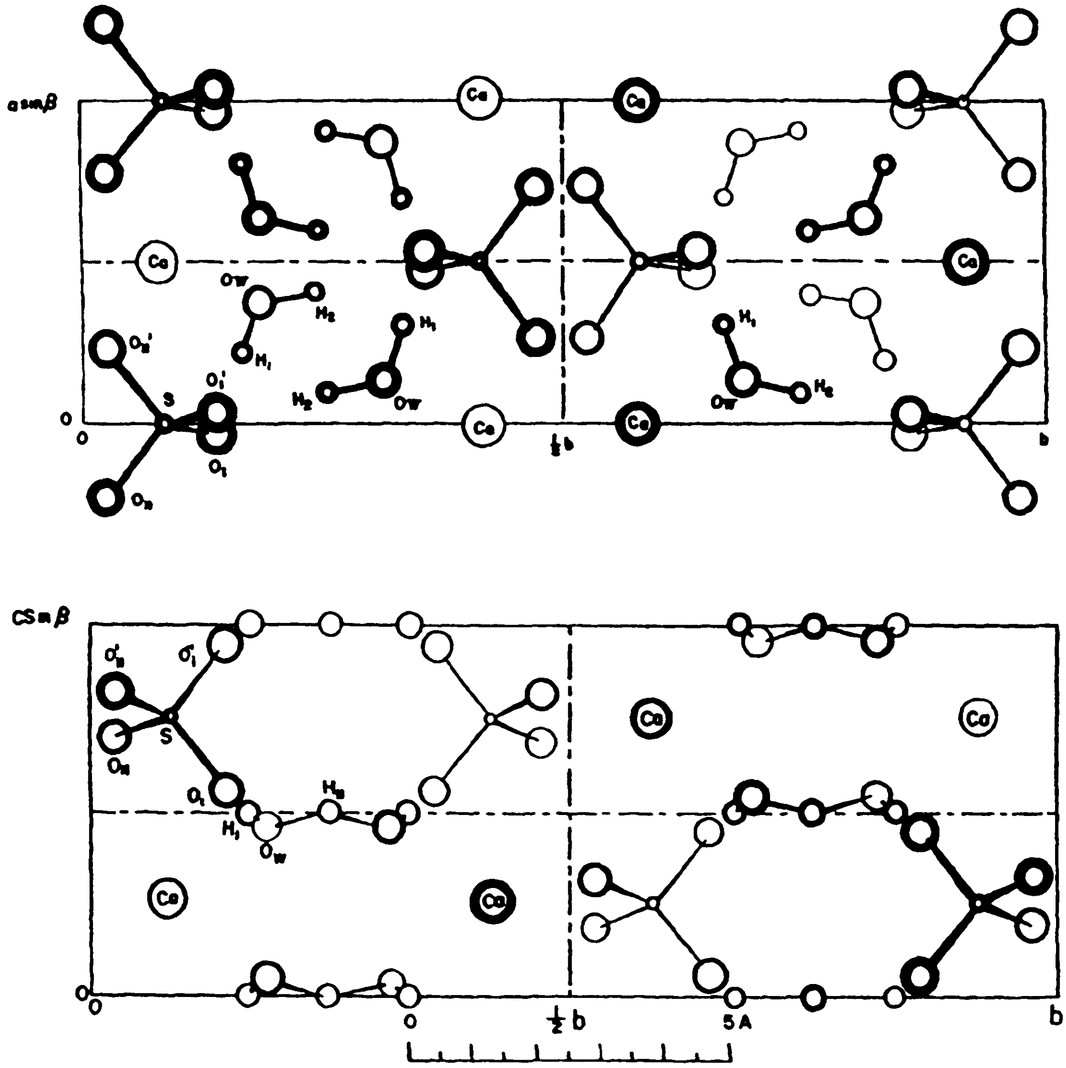


Fig.2.2: the structure of gypsum projected on the (001) and (100) planes, after Atoji & Rundle, 1958

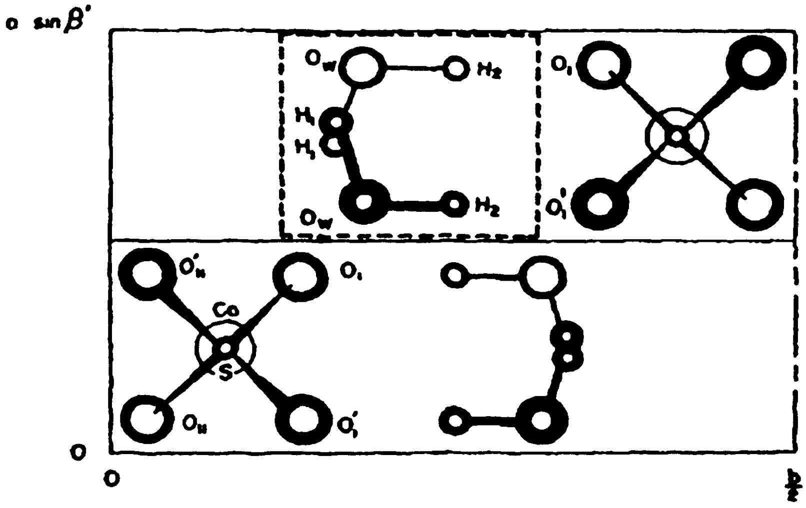


Fig.2.3: projection of gypsum structure on the (101) plane, after Atoji and Rundle, 1958

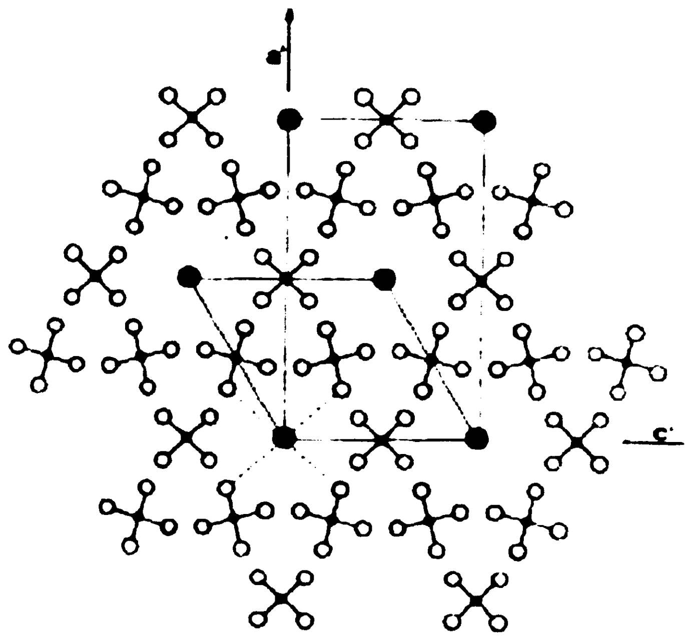


Fig.2.4: (001) projection illustrating the relationship between the hexagonal and monoclinic unit cells of γ-$CaSO_4$ and hemihydrate. The SO_4 tetrahedra and the channels are developed parallel to the c axis. The possible positions of H_2O are indicated by the large black circles at the centre of the channels, after Lager et al. 1984

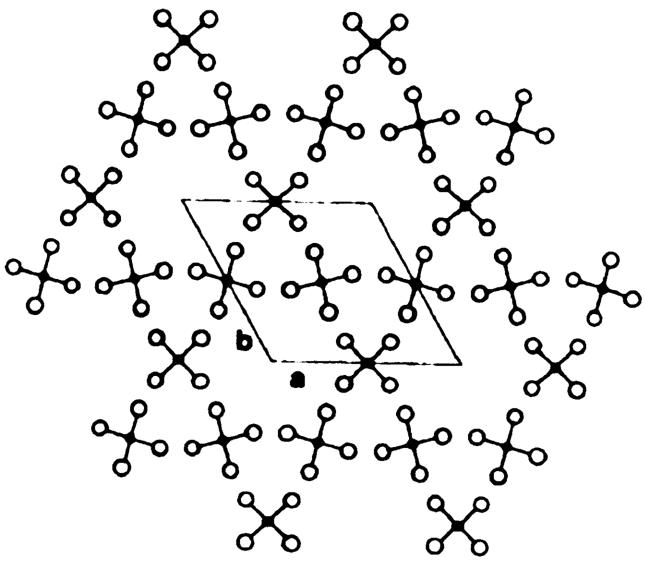


Fig.2.5: projection of γ-$CaSO_4$ on the (001) plan, illustrating the sulphate tetrahedra and the channels developed parallel to c axis, after Lager et al. 1984

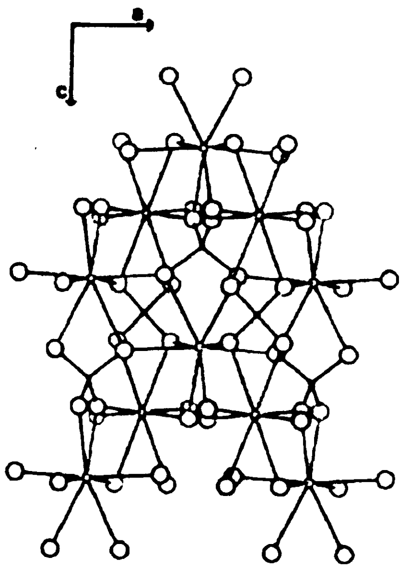


Fig.2.6: projection of γ-$CaSO_4$ on the (010) illustrating the edge sharing chains of SO_4 tetrahedra and CaO_8 polyhedra, after Lager et al. 1984)

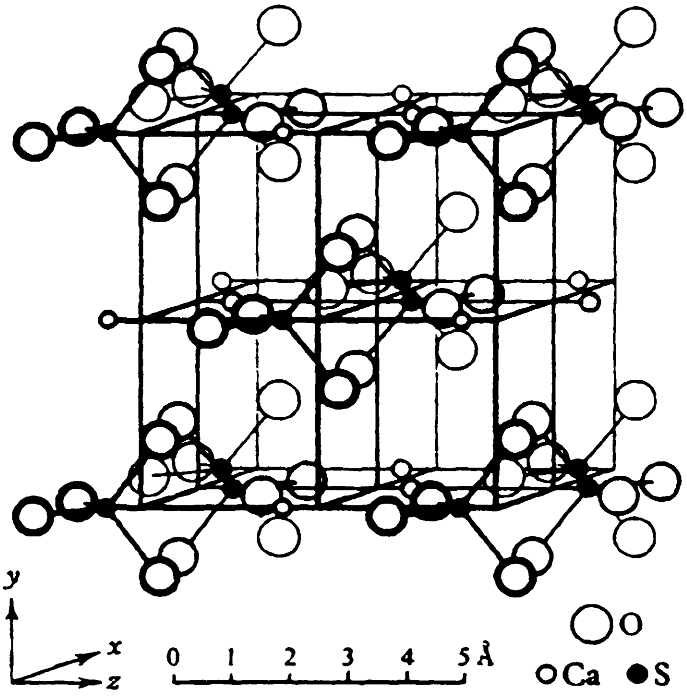


Fig.2.7: the structure of anhydrite, after Dickson & Bink, 1926 cited in Deer et al. 1966

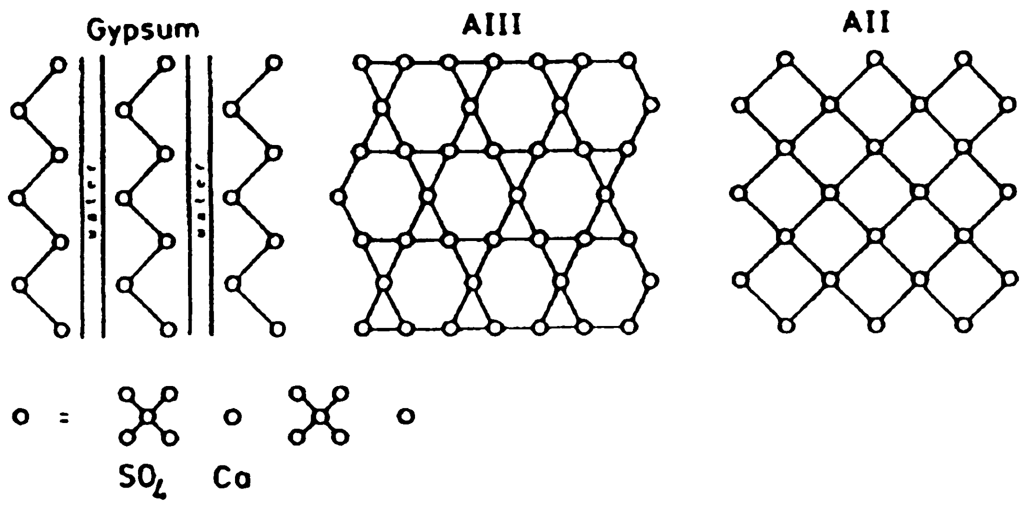


Fig2.8: basic structures in the system $CaSO_4$- H_20, after Abriel et al 1990

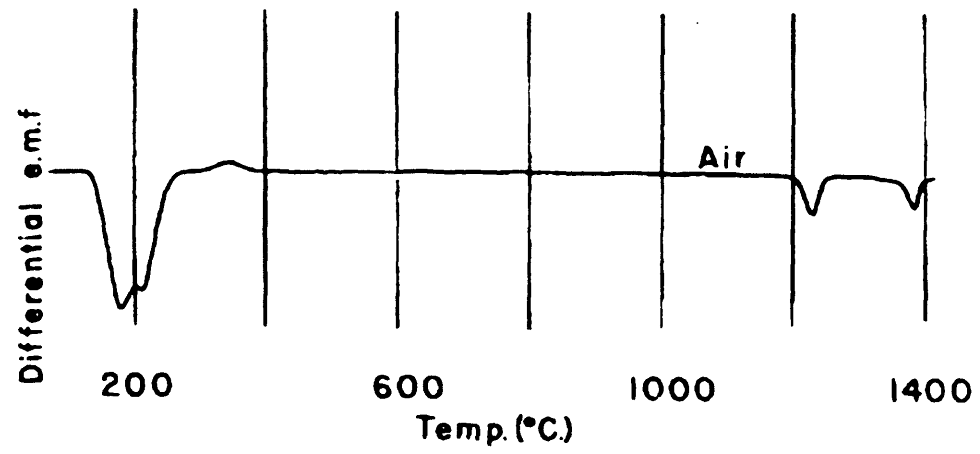


Fig.2.9: differential thermal analysis of gypsum according to Ljunggren 1960 and West & Sutton 1954

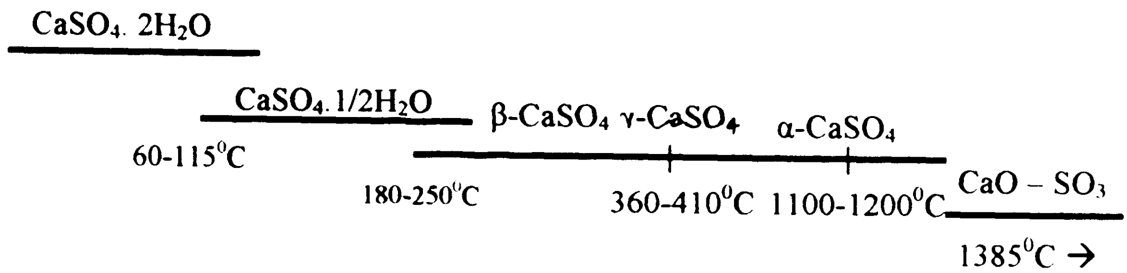


Fig.2.10: transition temperatures of calcium sulphate dihydrate and subhydrates

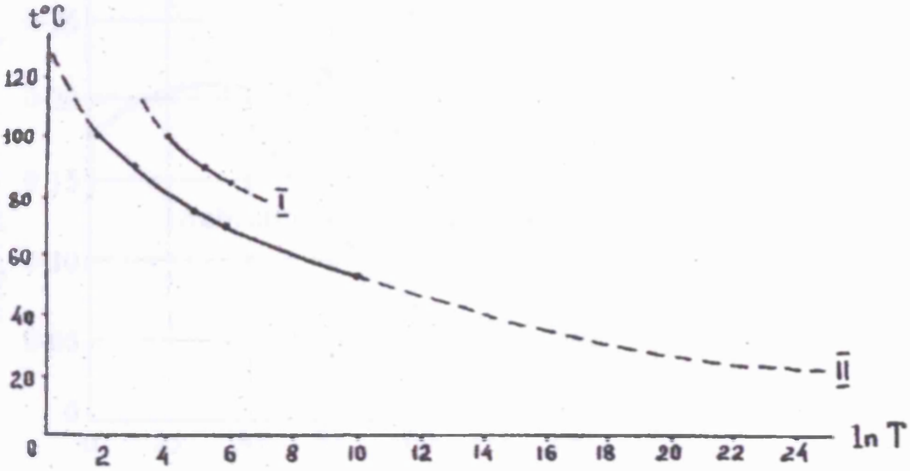


Fig.2.11: the dependence of change of time (T, hour) necessary for gypsum dehydration on the temperature (t^0C): I, up to $CaSO_4$ and II, up to $CaSO_4.0,5H_2O$, after Packorkin 1983

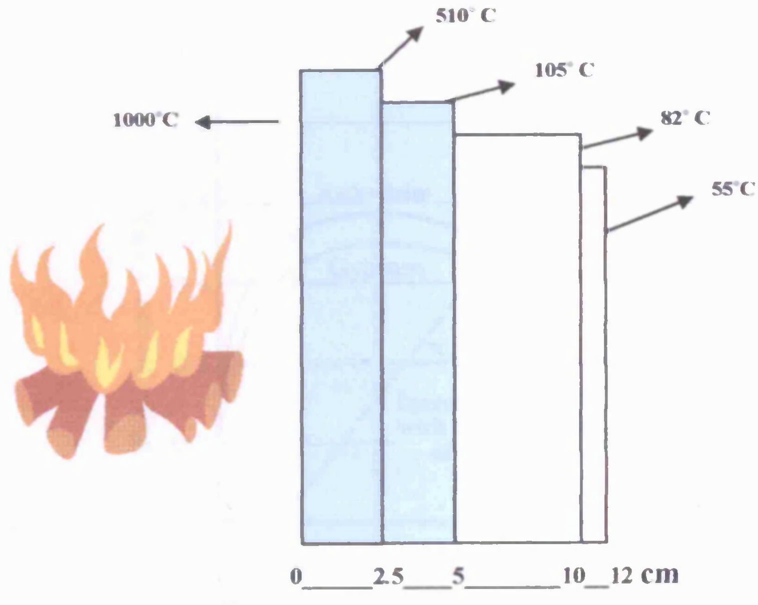


Fig.2.12: heat transfer after exposure of gypsum slab to fire for two hour (reproduced from Drougas 1980:5)

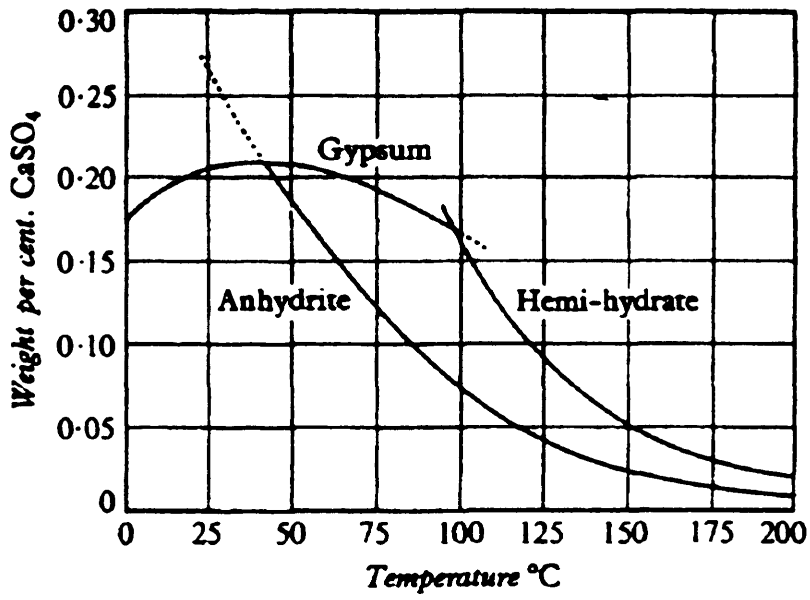


Fig.2.13: solubility of gypsum, anhydrite and the metastable hemi-hydrate in pure water, after Posnjak, 1938

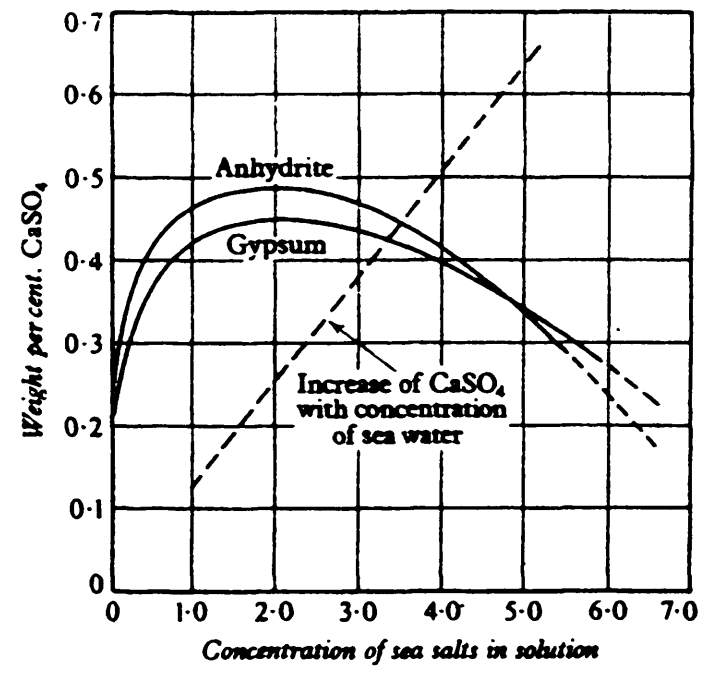


Fig.2.14: solubility curves for gypsum and anhydrite in solutions of sea salts at atmospheric temperature and pressure. Broken line shows amount of calcium sulphate that is available when ordinary sea-water is being evaporated. Concentration is expressed in units of the normal salinity of seawater (approx. 3.5 parts of salt per 1000 parts of solution), after Posnjak, 1940, cited in Deer et al. 1966

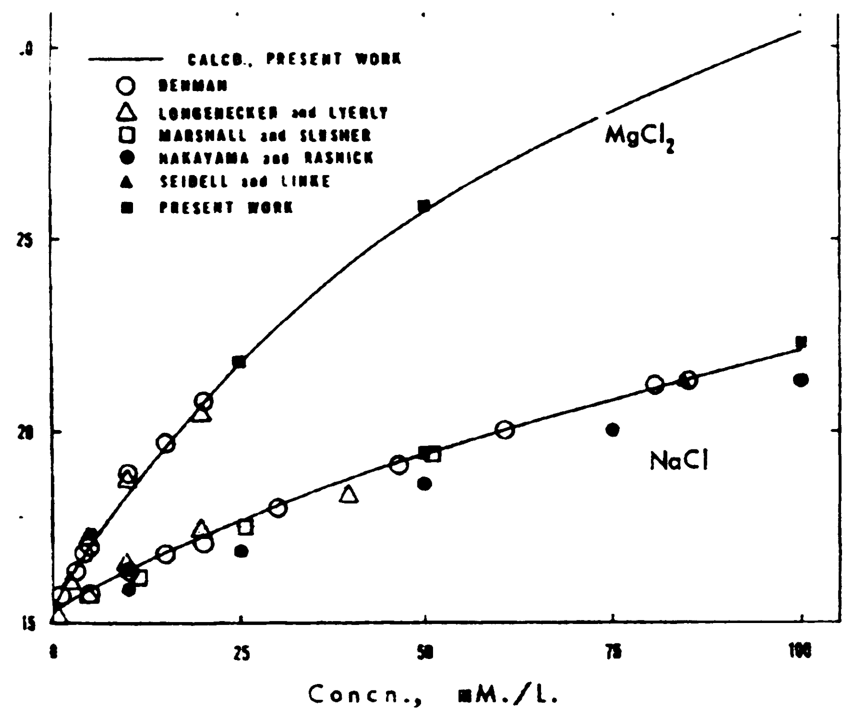


Fig.2.15: solubility of gypsum in various concentrations of NaCl and MgCl$_2$ solutions at 25°C, after Tanji 1969

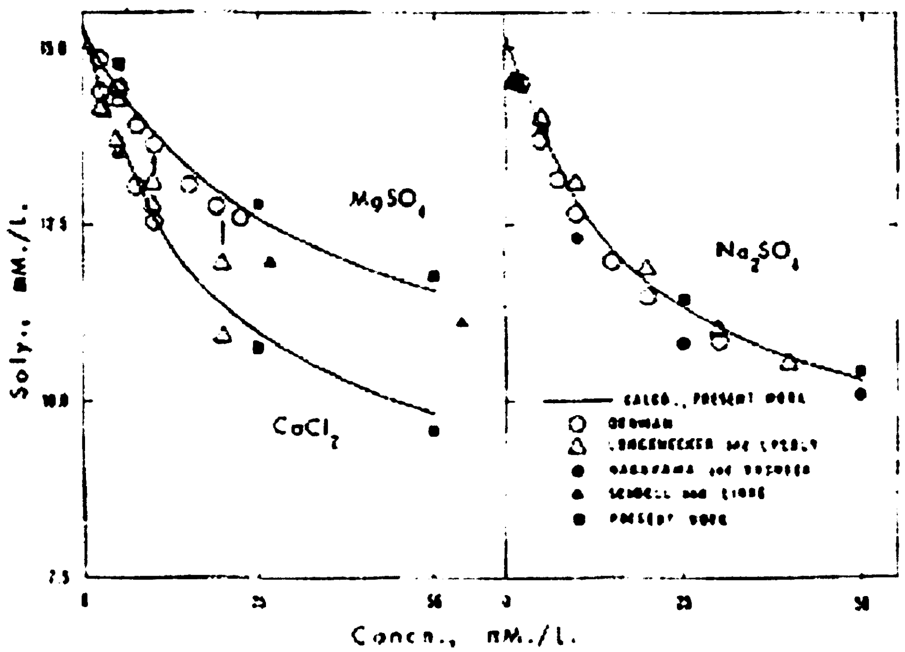


Fig.2.16: solubility of gypsum in various concentrations of CaCl$_2$, Na$_2$SO$_4$ and MgSO$_4$ solutions at or near 25°C, after Tanji 1969

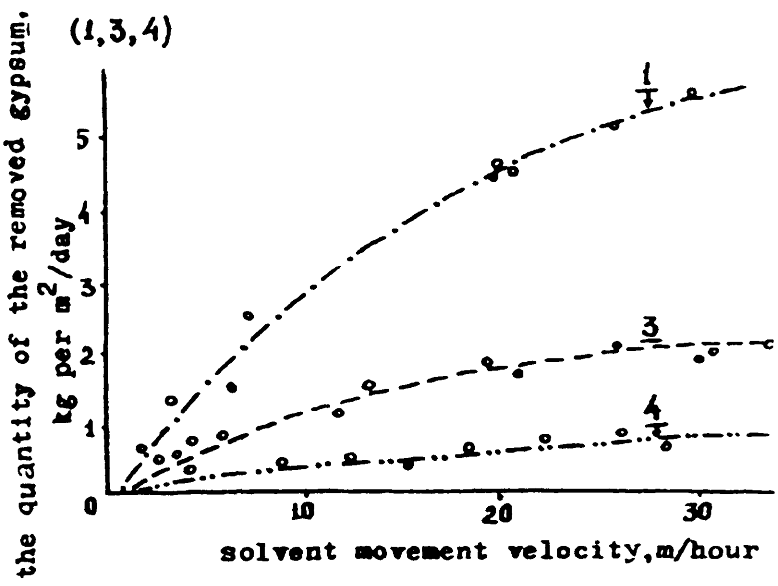


Fig.2.17: dependence of gypsum dissolution on the water movement velocity: 1-crushed rock in distilled water, 3- rock monoliths in natural water under forced mixing and 4-under laminar water movement, after Peckorkin 1983

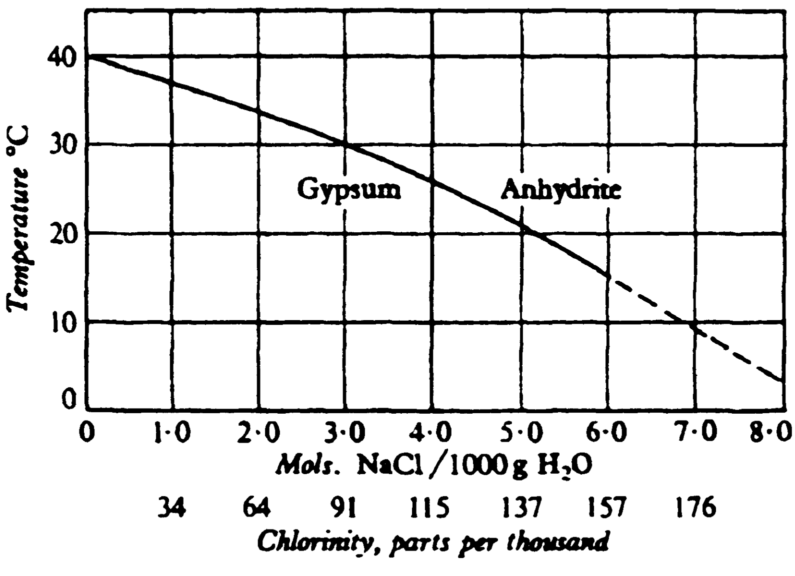


Fig.2.18: dependence of the dehydration temperature of gypsum on concentration of NaCl in solution at 1 Bar pressure, after Macdonald 1953, cited in Deer et al. 1966

	Evaporite Type	Precipitation Process	Temperature	Hydrological Process	Base metal association	
An evaporite is a rock that was originally precipitated from a saturated surface or near surface brine by processes driven by solar evaporation	Primary or depositional evaporite	An evaporite salt precipitated via solar evaporation from a brine pool at the earths's surface	0-50^{0}C	Gravity and density effects at surface or in zone of active phreatic flow (brine reflux)	Saturation driven by solar evaporation	Dissolution of these evaporite beds can act as a source of chloride to form metal transporting chlodire brines
	Secondary evaporites	An evaporite salt formed in a the shallow subsurface in the zone of active phreatic flow. The concentration process of the brine and the associated gravitational reflux is driven by solar evaporation. May form displacive, replacive or cement textures Burial diagenetic evaporite phase that replaces earlier evaporite beds. Salt precipitation is driven by fluid mixing or saturation mechanisms driven by burial diagenetic processes. Forms replacive and cement textures	50-200^{0}C	Burial effects compactional and thermobaric flow	Brine saturation not driven by directly by solar evaporation	Sulphate beds can act as source of sulphur both transported and 'in situ' Typical association with indicators of the 'evaporite that was'
	Burial Salts	Subsurface precipitation of evaporite as cements and replacements in non-evaporite matrix from saturated brine derived from the dissolution of adjacent evaporite beds	0-60^{0}C	Stagnant to active phreatic flow		
	Tertiary Evaporites	An evaporite formed by brine saturation related to partial bed dissolution via re-entry into the zone of active phreatic circulation. Often driven by basin uplift and erosion	T>200^{0}C	Hydrothermal circulation		Evaporites reflect ambient temperature and precipitation conditions associated with ore
	Hydrotherm al Salts	Evaporite minerals precipitated by the cooling or mixing of hydrothermal waters				

Table 2.2: evaporite classification with regard to the to the range of surface and subsurface settings where evaporite salts can be found, after K. J. Warren 1996

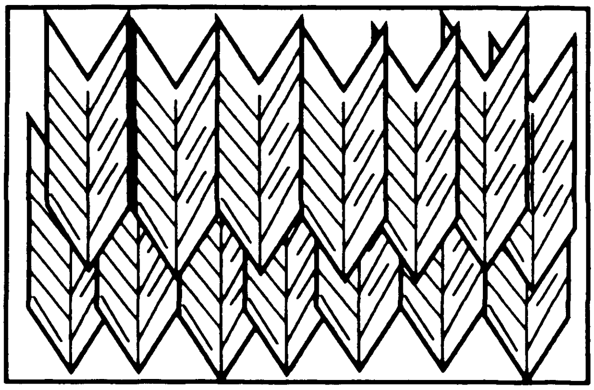


Fig.2.19: Selenite with arrowhead crystals.

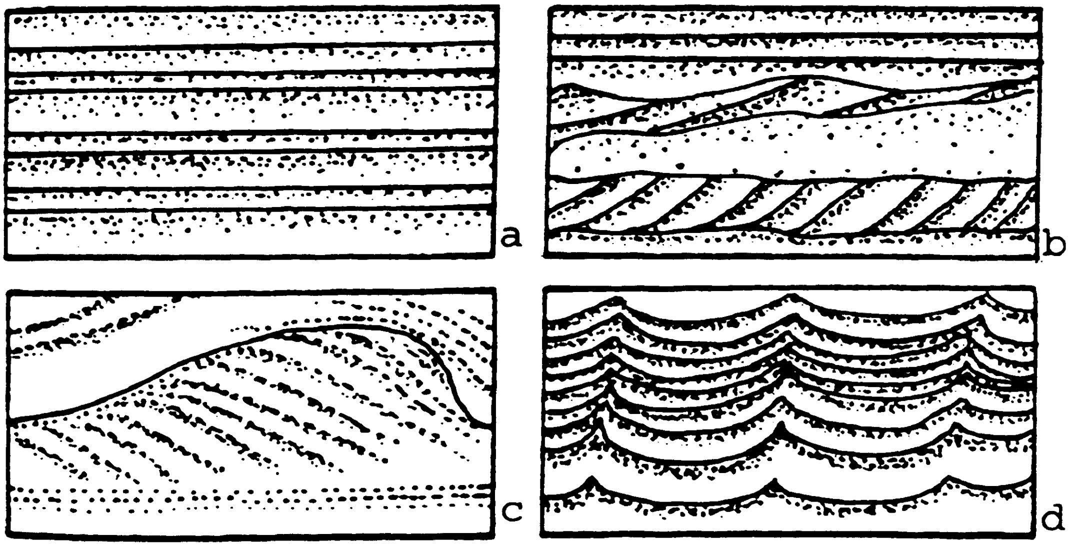


Fig.2.20: a) even laminations (1x), b) cross stratified (1x), c) climbing ripples (1 4x) and d) oscillation ripples (1 10x), after Schreiber 1978

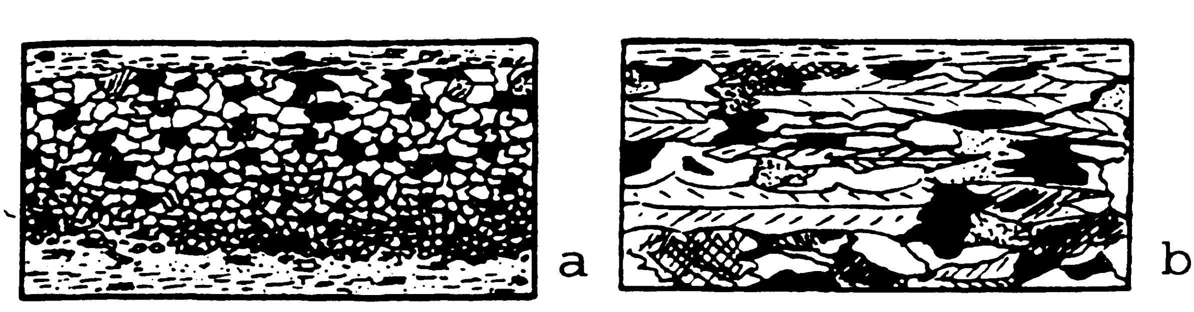
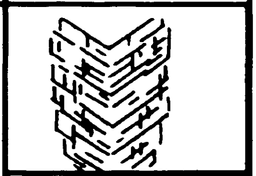
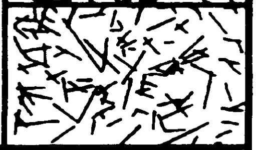
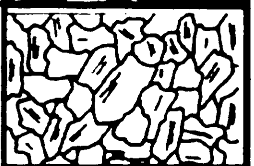
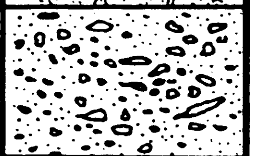


Fig. 2.21: a) layer of laminated gypsum showing reverse grading and b) layer of laminated gypsum where the original primary crystals are visible (10x), after Schreiber 1978. Both specimens show the same macroscopic characteristics and can not be distinguished with the naked eye

Form	Grain Size	Crystal Shape	
Primary Idiotopic	Macrocrystalline > 0.5m-1m or more	Twinned selenite (arrow head or swallow tail)	
		Prismatic	
	Crystalline > 0.5 m -1m or more	Lenticular	
		Accicular	
Xenotopic	Macrocrystalline	Cloudy Stellate	
		Cloudy Ameboid	
	> 0.6 mm	Granular	
	Microcrystalline < 0.06 mm	Nodular (Alabaster)	
Clastic	clasts > 0.06 mm < 2 mm	Gypsarenite	
	clasts > 2 mm	Gypsrudite	

0,5mm

Table 2.3: classification of gypsum based on crystal shape and size, according to Ciarapica, Passeri and Shcreiber 1985

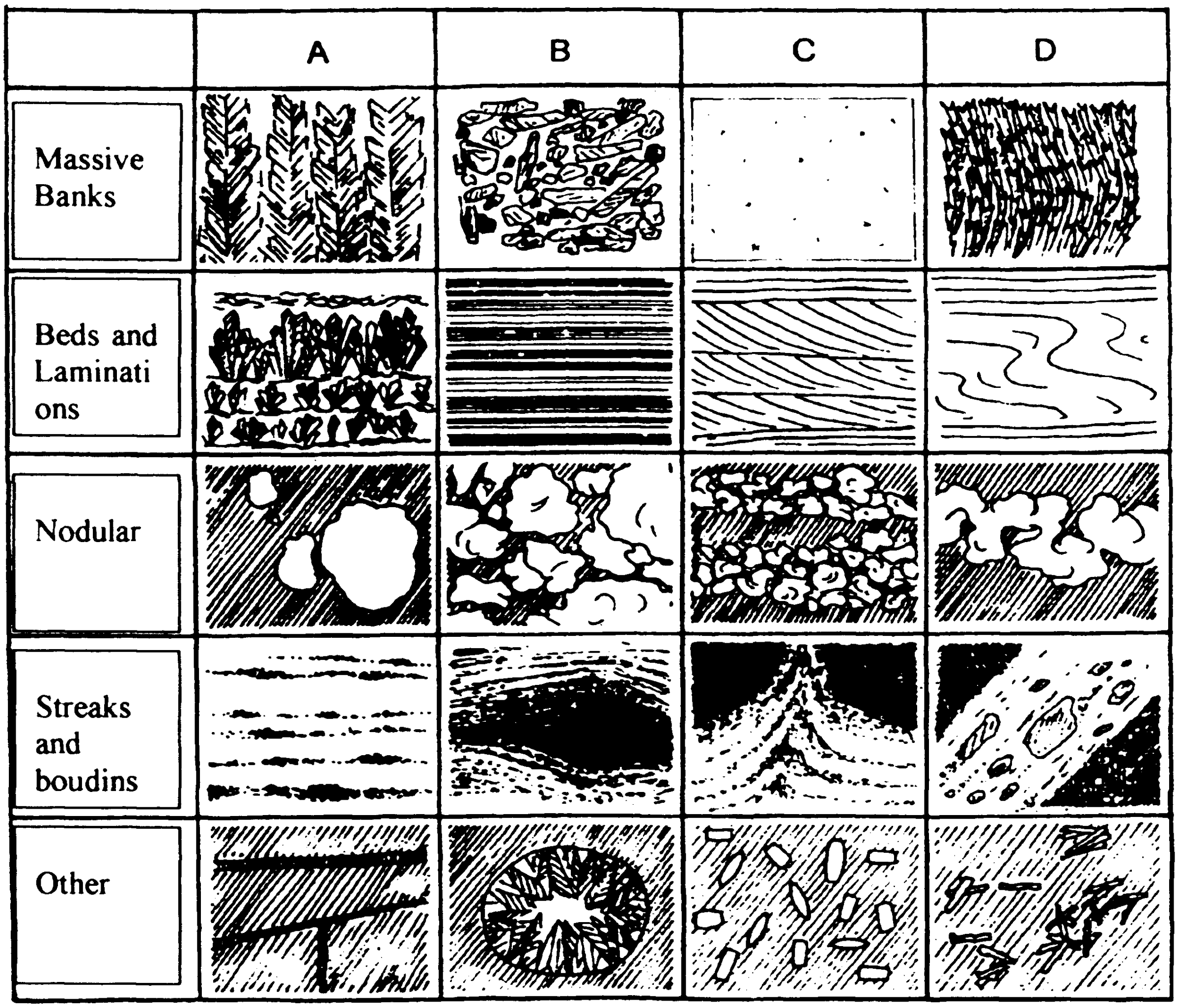


Table 2.4: structure of evaporite deposits, after Ciaparica et al. 1985

Massive Banks: A) idiotopic arrow-head gypsum in primary growth (selenite or primary gypsum, B) clastic gypsum (gypsarenite, gypsrudite, primary or syndepositional, C) re-crystallised gypsum or anhydrite (microcrystalline or alabastrine, formed after diagenesis), D) distorted idiotopic gypsum (primary deposition)

Laminations and beds: A) alternating layers of idiotopic arrow-head gypsum and other material (clays or carbonates) B) sulphate rocks in parallel bedding, C) sulphate rocks in cross bedding, D)sulphate rocks in distorted bedding

Nodules A) sulphate nodules scattered in a non- sulphate matrix B) packed nodules in a massive arrangement, C) nodular bedded sulphates, D) distortion in nodular structures

Streaks and boudins A) sulphate with streaks of dolomitic fragments, B) dolomitic boudin in a streaked sulphate, C) flame structure in a streaked sulphate D) streaked sulphate dyke in a dolomitic body.

Other Structures: A) 'satin spar' growth in a host structure, B) sulphate precipitated in a cavity, C) axe-headed anhydrite crystals in a carbonate rock, D) fibrous anhydrite crystals scattered in a carbonate rock

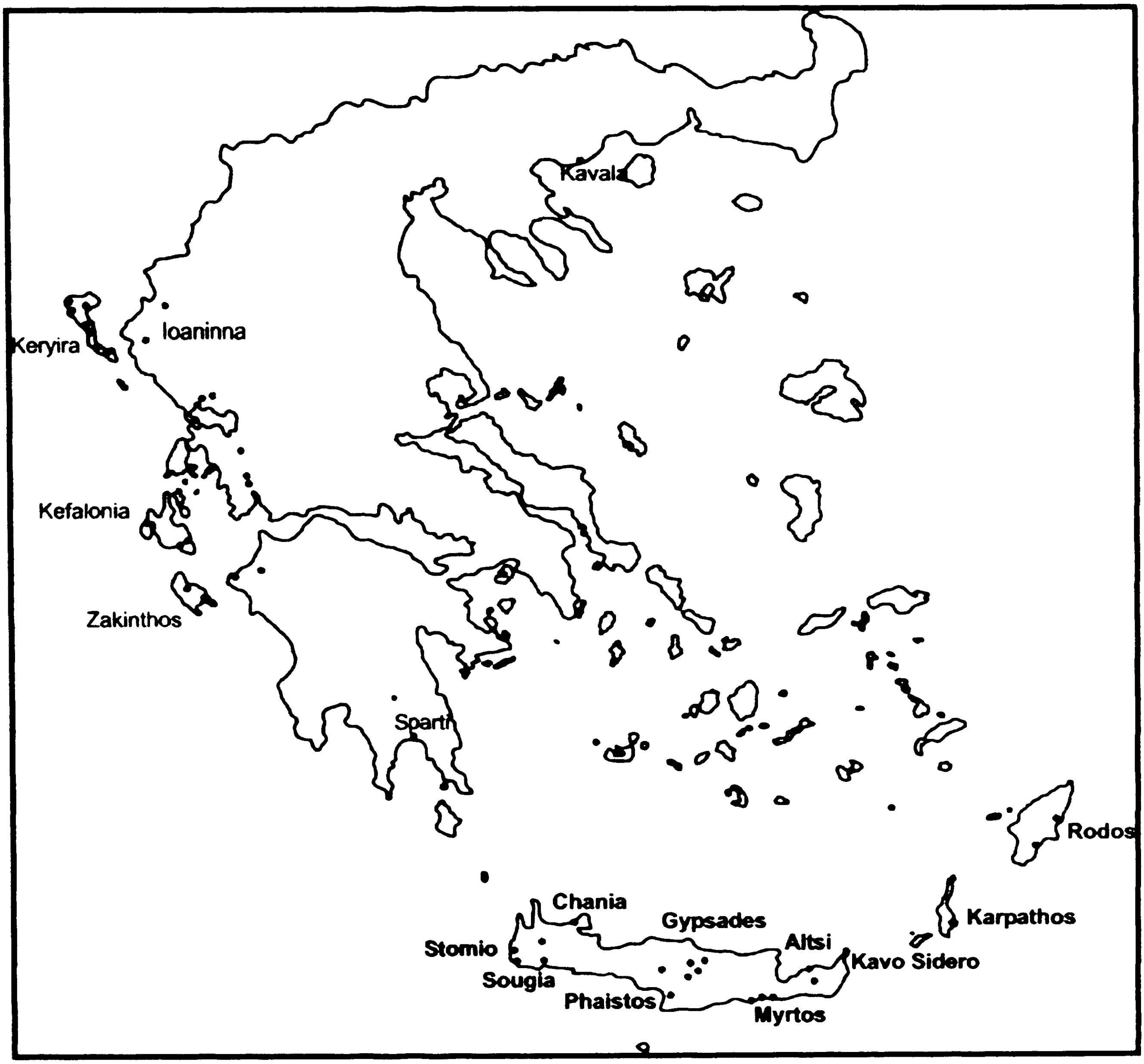


Fig. 3.1: distribution of gypsum outcrops in Greece

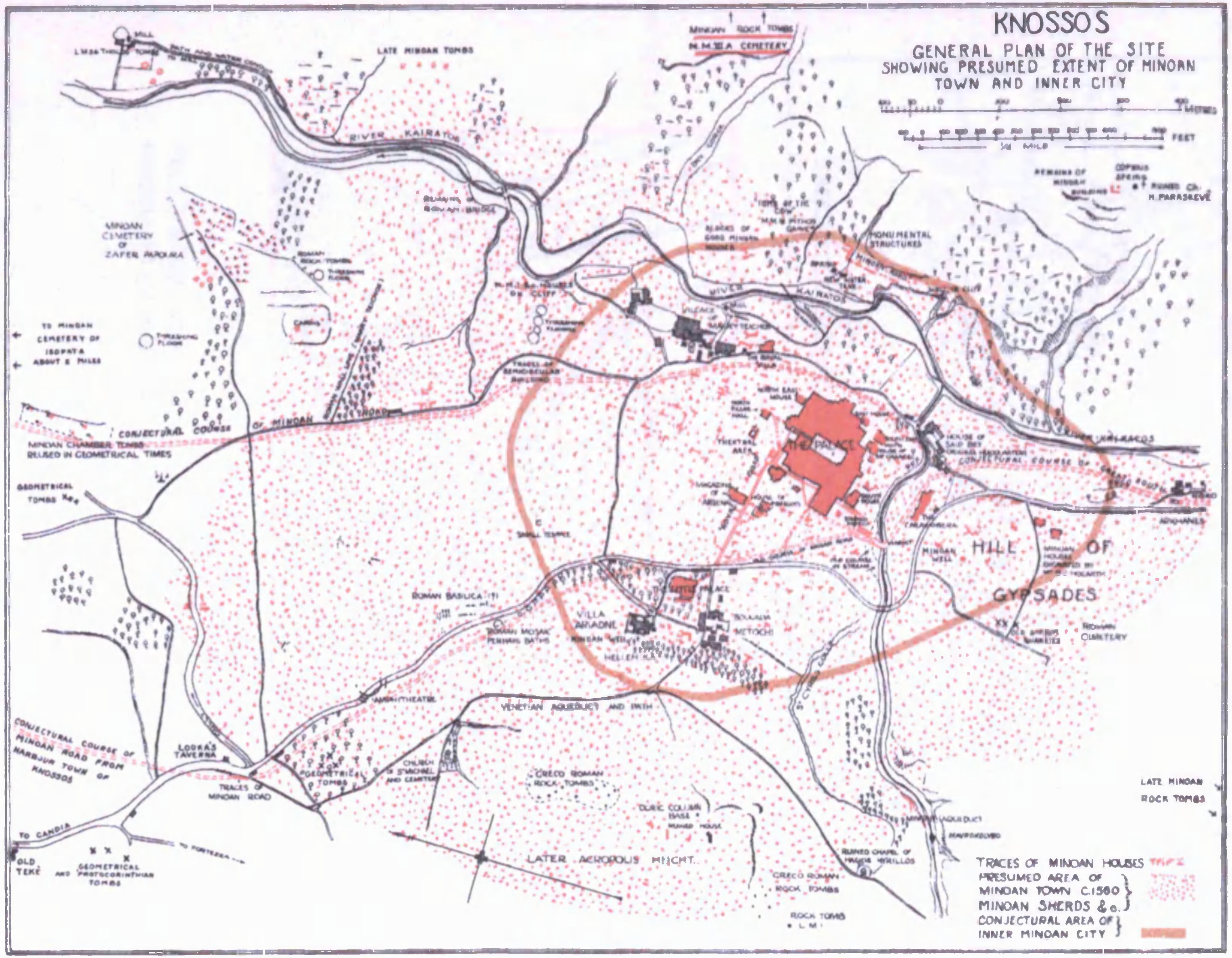


Fig.3.2: the outcrop of Gypsades with 'old gypsum quarries' as published by Evans (1928:547)

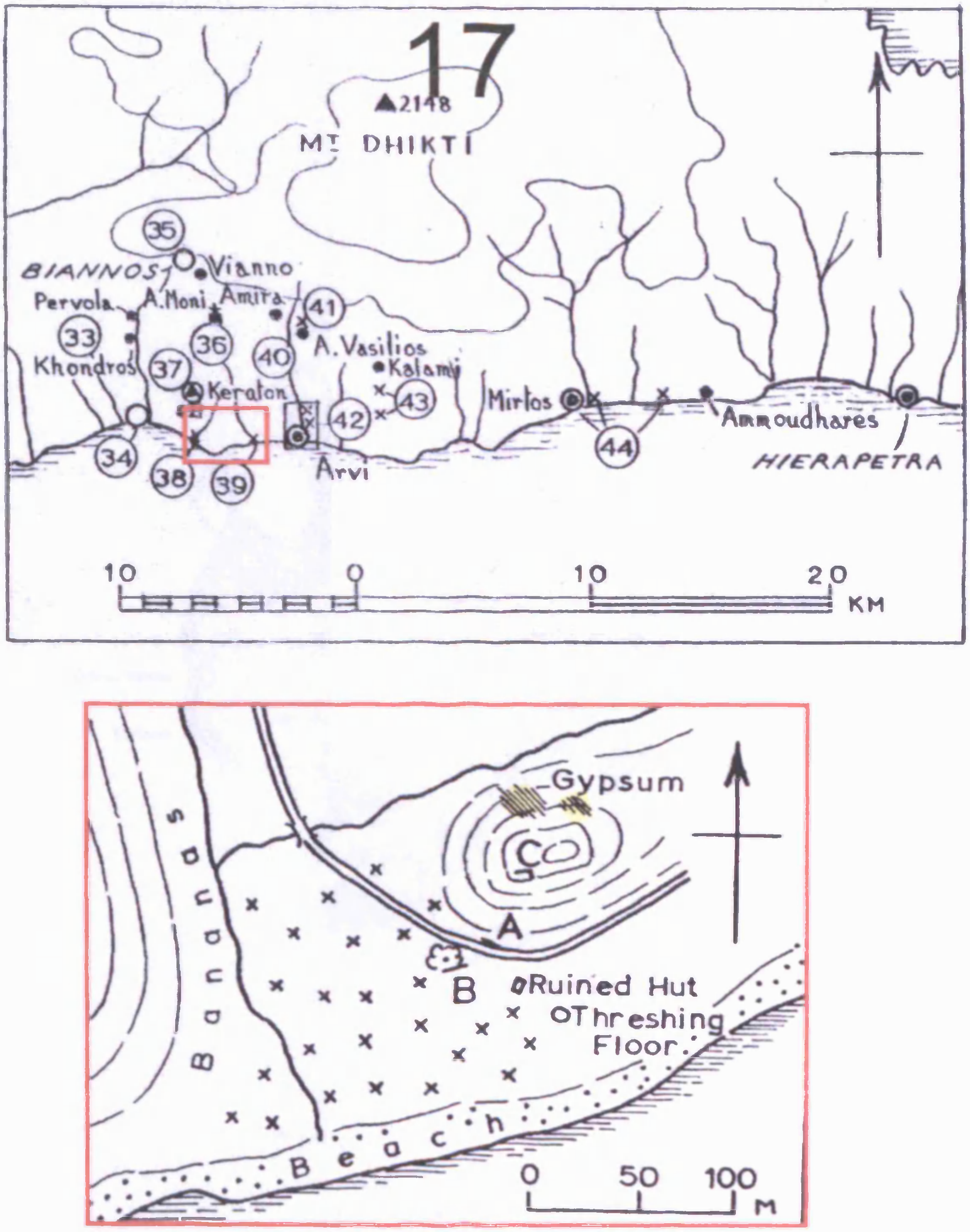


Fig.3.3: schematic map of the area west of Ierapetra with detail marking the gypsum outcrop of Trokhaloi, after Hood *et al.* 1964

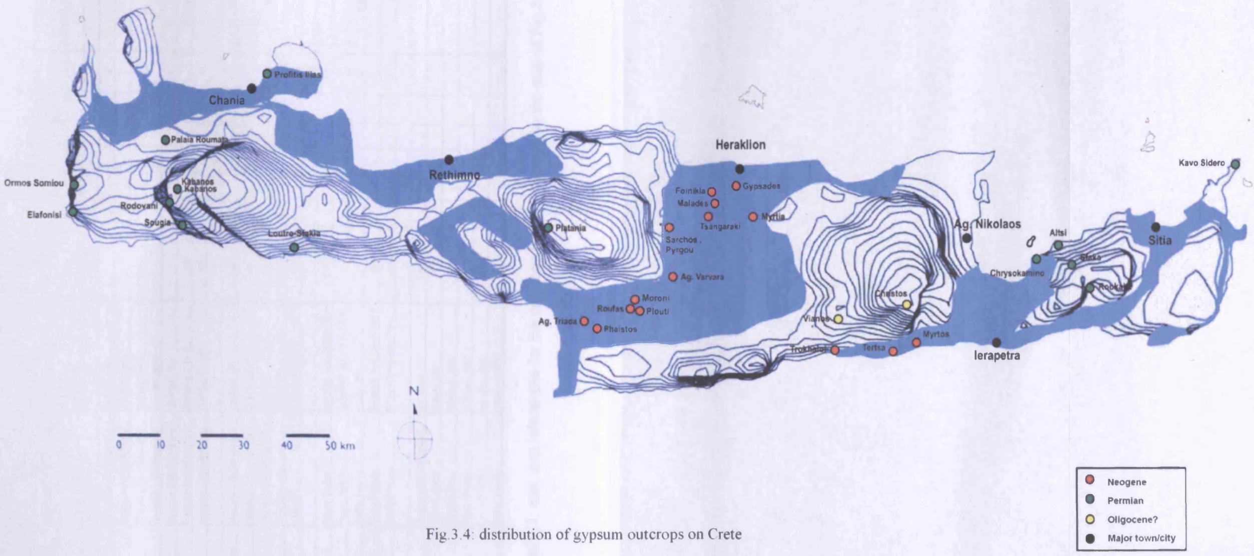


Fig 3.4: distribution of gypsum outcrops on Crete

Toponyms	Age of Formation	IGME Geological Map	IGME Metalographic	K	G	D	Z	R	Exaxhimed	Other references
Gypsades or Knossos	Neogene (Late Messinian)	Heraklion 1996	G49		x		x		x	Papageorgakis 1988, Hood 1981, Evans 1928,1930
Foinikia	Neogene (Late Messinian)	Heraklion 1996		x				x	x	
Malades	Neogene (Late Messinian)	Heraklion 1996							x	
Tsangaraki	Neogene (Late Messinian)	Epano Archanes 1994	G50	x	x			x	x	
Pyrgos	Neogene (Late Messinian)*	Epano Archanes 1994						x	x	
Sarchos - Pyrgou or Krousonas	Neogene (Late Messinian)*	Epano Archanes 1994	G51	x	x	x	x		x	
Agia Barbara	Neogene (Late Messinian)	not shown						x	x	
Myrtia	Neogene (Late Messinian)	not shown							x	Warren P., Rethemniotakis G., pers comm 2003
Platania	Permo-Triassic	not shown	G53		x		x			
Plouti	Neogene (Late Messinian)	Tymbaki 1984		x					x	Dermitzakis et al. 1990
Roufas	Neogene (Late Messinian)	Tymbaki 1984		x					x	Dermitzakis et al. 1990
Moroni	Neogene (Late Messinian)	Tymbaki 1984		x					x	Dermitzakis et al. 1990
Akria-Kastelli	Neogene (Late Messinian)	Tymbaki 1984								Lugli, S. pers comm 2004
Gortyn Cave or Labirynth	Neogene (Late Messinian)	Tymbaki 1984		x		x			x	Dermitzakis et al. 1990
Phaistos	Neogene (Late Messinian)	Anitskarion 1985	G52		x		x			Pernier 1951, Shaw 1973, Levi 1976
Agia Triada	Neogene (Late Messinian)	Anitskarion 1985	G52		x				x	Shaw 1973, Levi 1976
Myrtos - Anatoli - Ammoudares	Neogene (Late Messinian)	Ierapetra 1993	G44	x		x	x		x	Antoniou 1987, Cadogan 1977, Hood et al. 1984
Tertsa	Neogene (Late Messinian)	Ierapetra 1993	G45-46	x		x	x		x	
Trokhaloi	Neogene (Late Messinian)	not shown	G48		x		x			Hood et al. 1984
Christos	Oligocene	not shown	G43		x		x			
Vianos	Oligocene	Ano Viannos 2002	G47		x	x	x		x	
Altsi	Permo-Triassic	Ierapetra- Kato Chorio 1959	G39-41	x	x	x	x		x	Antoniou 1987
Sfaka	Permo-Triassic	Ierapetra-Kato Chorio 1959		x		x	x		x	Antoniou 1987
Chrysokamino**	Permo-Triassic	not shown							x	Betancourt 2000 pers comm.
Roukaka or Chrysopigi	Permo-Triassic	Ierapetra Kato Chorio 1959	G42		x	x	x		x	Bosanquet 1902
Kavo Sidero	Permo-Triassic	Siteia - Dionysades 1959	G38		x	x	x		x	
Chania (Profitis Ilias)	Neogene (Late Messinian)	not shown	G54		x		x			
Loutro -Sfakia	Permo-Triassic	Vrisses 1993								
Palaia Roumata	Permo-Triassic	Alikianou 1969	G55	x	x		x			
Kabanos	Permo-Triassic	Alikianou 1969		x					x	
Rodovani or Kamaria	Permo-Triassic	Alikianou 1969	G56	x	x		x			
Sougia	Permo-Triassic	Alikianou 1969	G57	x	x	x	x		x	

Table 3.1: age, and references for the outcrops that are marked on the map of Fig.3.4

Fig.3.5: Permian outcrop of gypsum at Altsi, east Crete

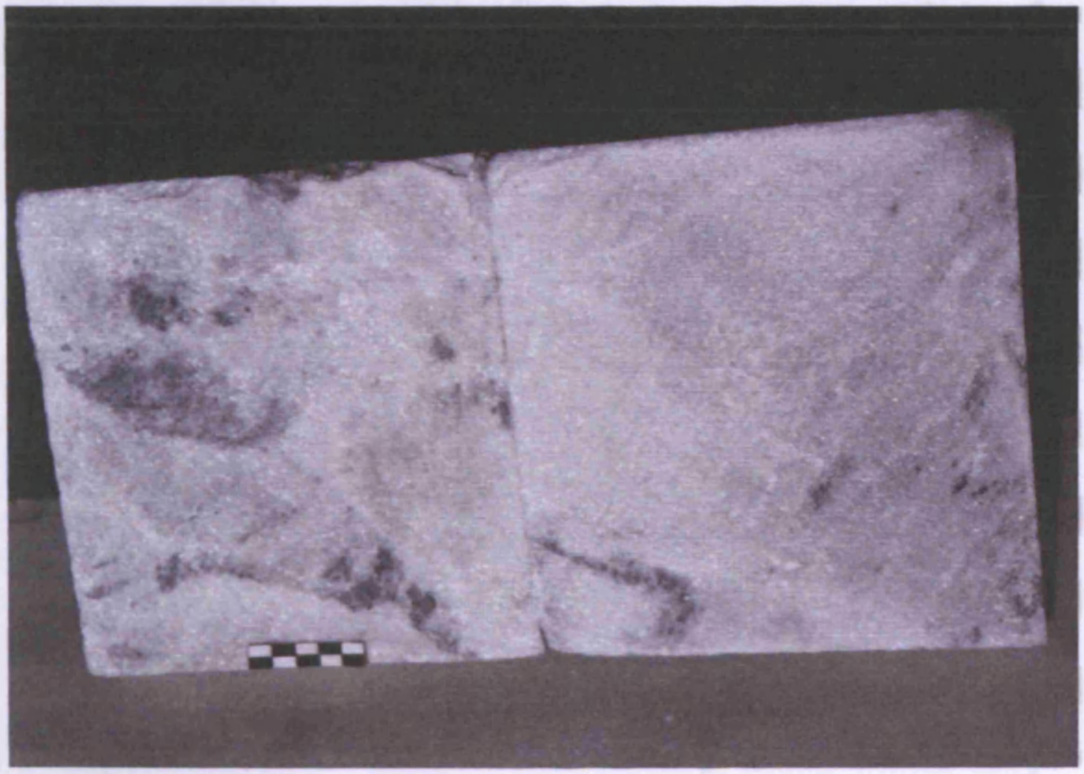


Fig.3.6: Permian gypsum from the outcrop of Altsi

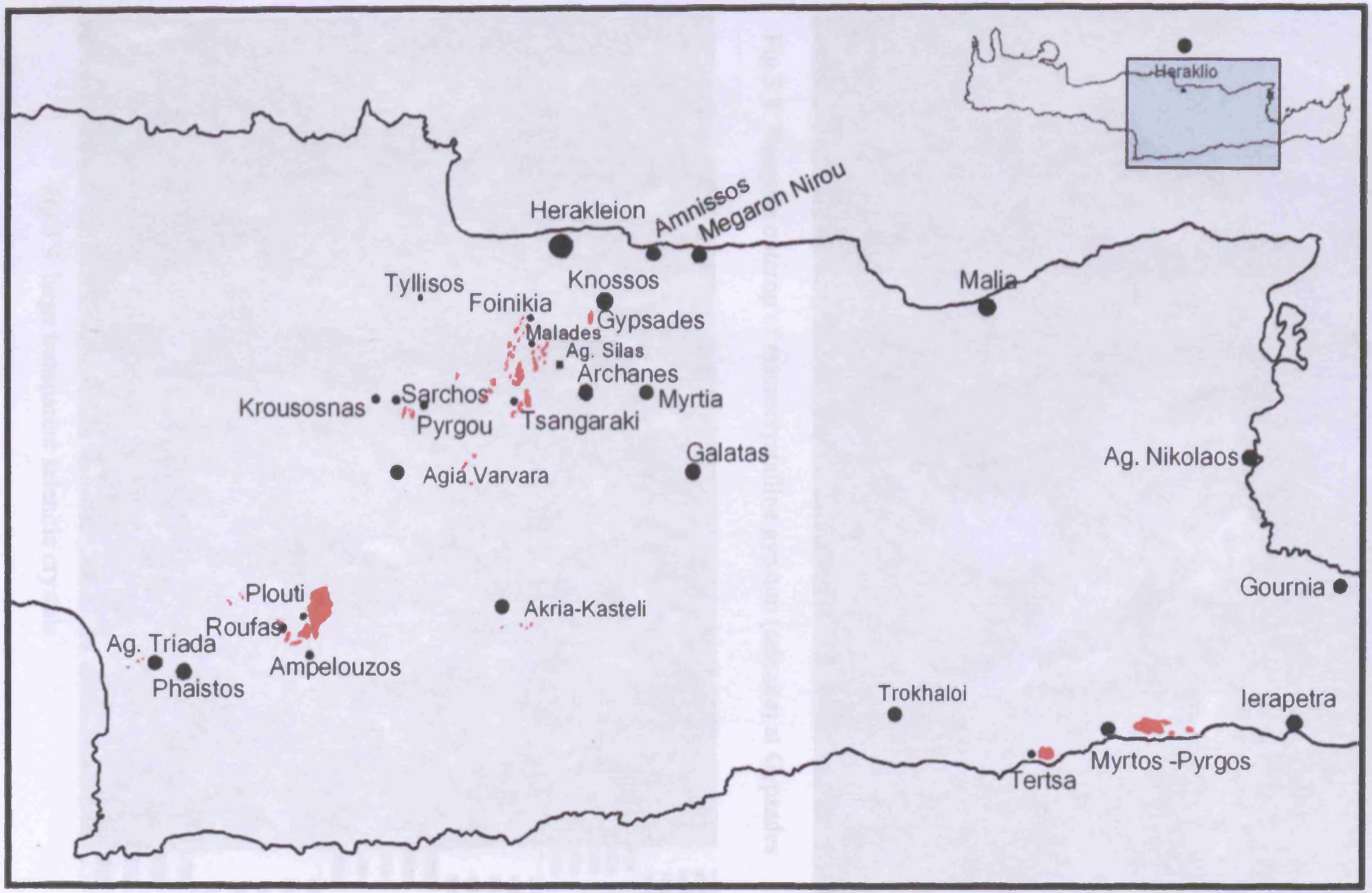


Fig.3.7: Neogene outcrops of central and east Crete

Fig.3.8: Neogene outcrop of macrocrystalline gypsum (selenite) at Gypsades

Fig.3.9: large transparent selenitic crystals

Fig.3.10: laminated gypsum or balatino outcrop, Plouti, Messara

Fig.3.11: laminated gypsum at the outcrop of Plouti, Messara

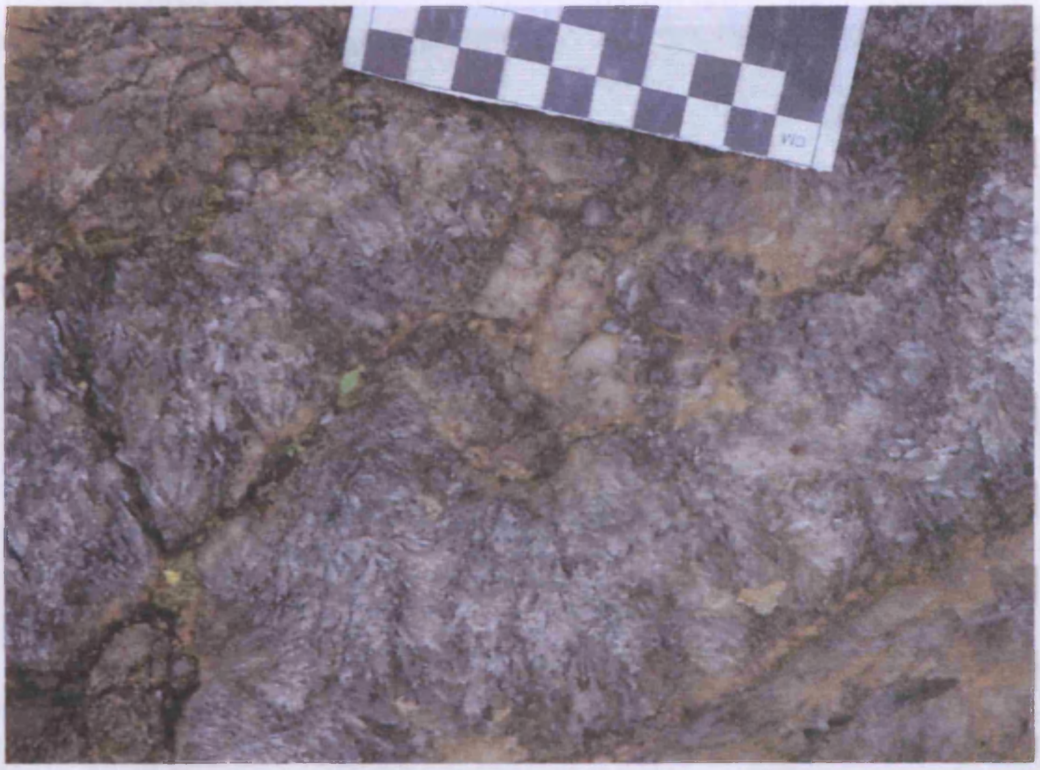


Fig.3.12: chaotic gypsum at the outcrop of Agia Triada, Messara

Fig.3.13: chaotic gypsum slab used in Levi's restorations at Phaistos, Room 50

Fig.3.14: Levi's modern quarrying operations at the Minoan quarry of gypsum at Agia Triada, (photo courtesy of the Italian School of Archaeology No1149, also published by Shaw:1973:43, fig.33)

Fig.3.15: Minoan quarry of Agia Triada (photo taken By P.Betancourt in 1983)

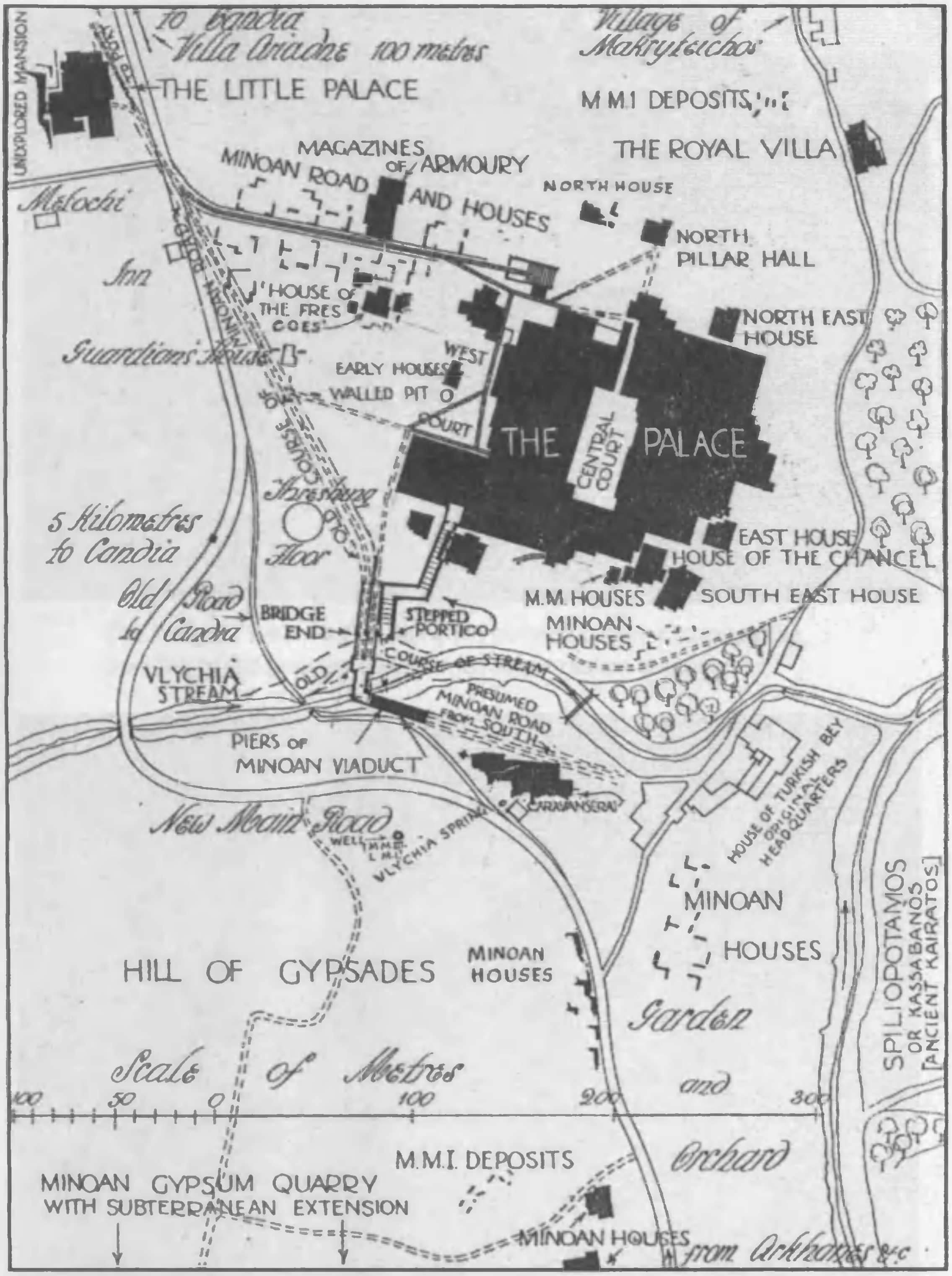


Fig.3.16: Evans' sketch plan of the Knossos area, including the Gypsades hill and the 'Minoan gypsum quarry with subterranean extension (Evans 1928:140, fig.71)

Fig.3.17: the location that has been pointed out by Evans' as the opening of the gypsum quarry with subterranean extension

Fig.3.18: nodular and lenticular (left) and massive selenite (right) at Evans' gypsum quarry

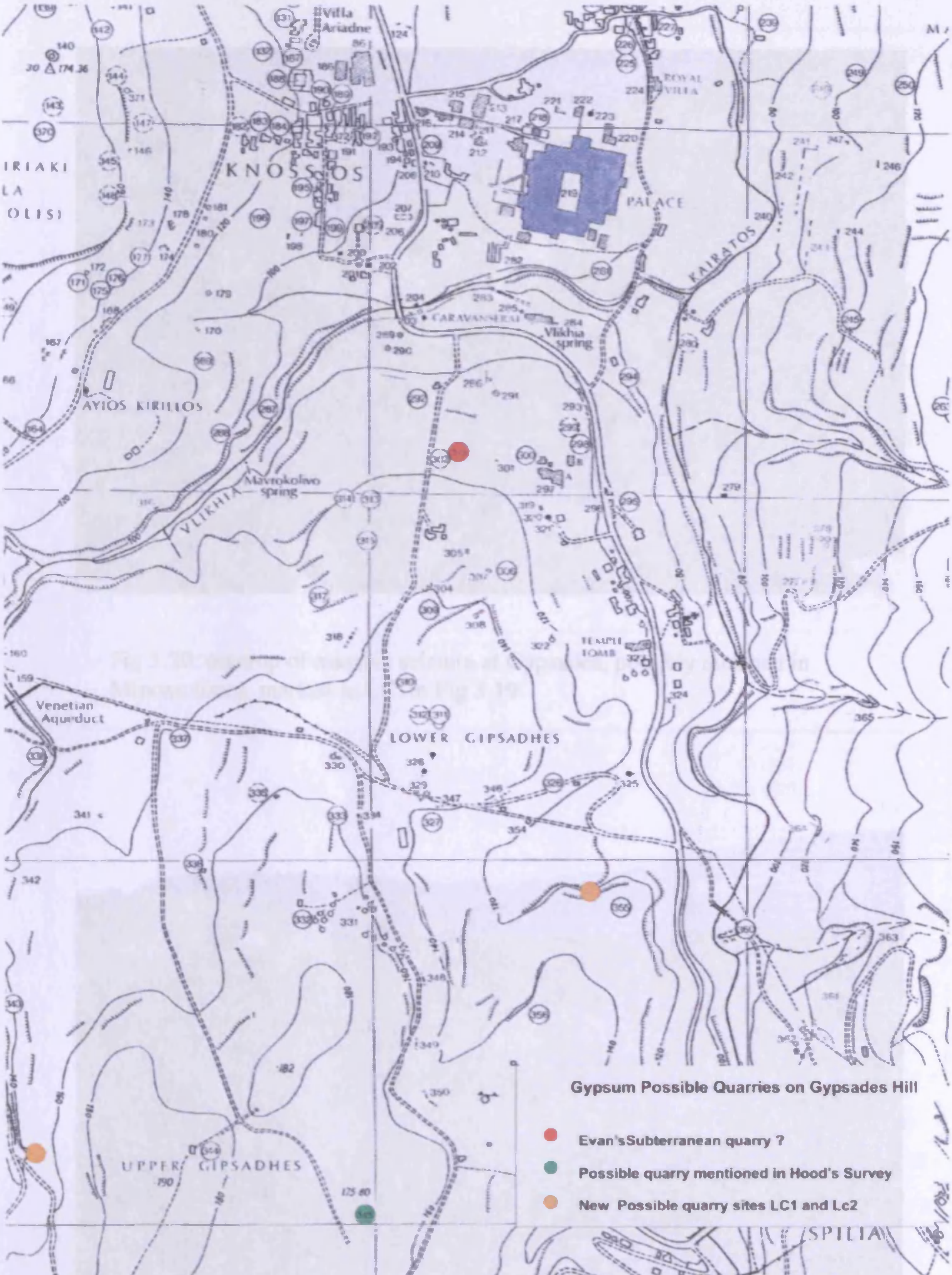


Fig.3.19: possible gypsum quarries on Gypsades Hill

Fig.3.20: outcrop of massive selenite at Gypsades, possibly quarried in Minoan times, marked as LC1in Fig.3.19

Fig.3.21: outcrop of massive selenite at Gypsades, with two terraces possibly quarried in Minoan times, marked as LC2 in Fig.3.19

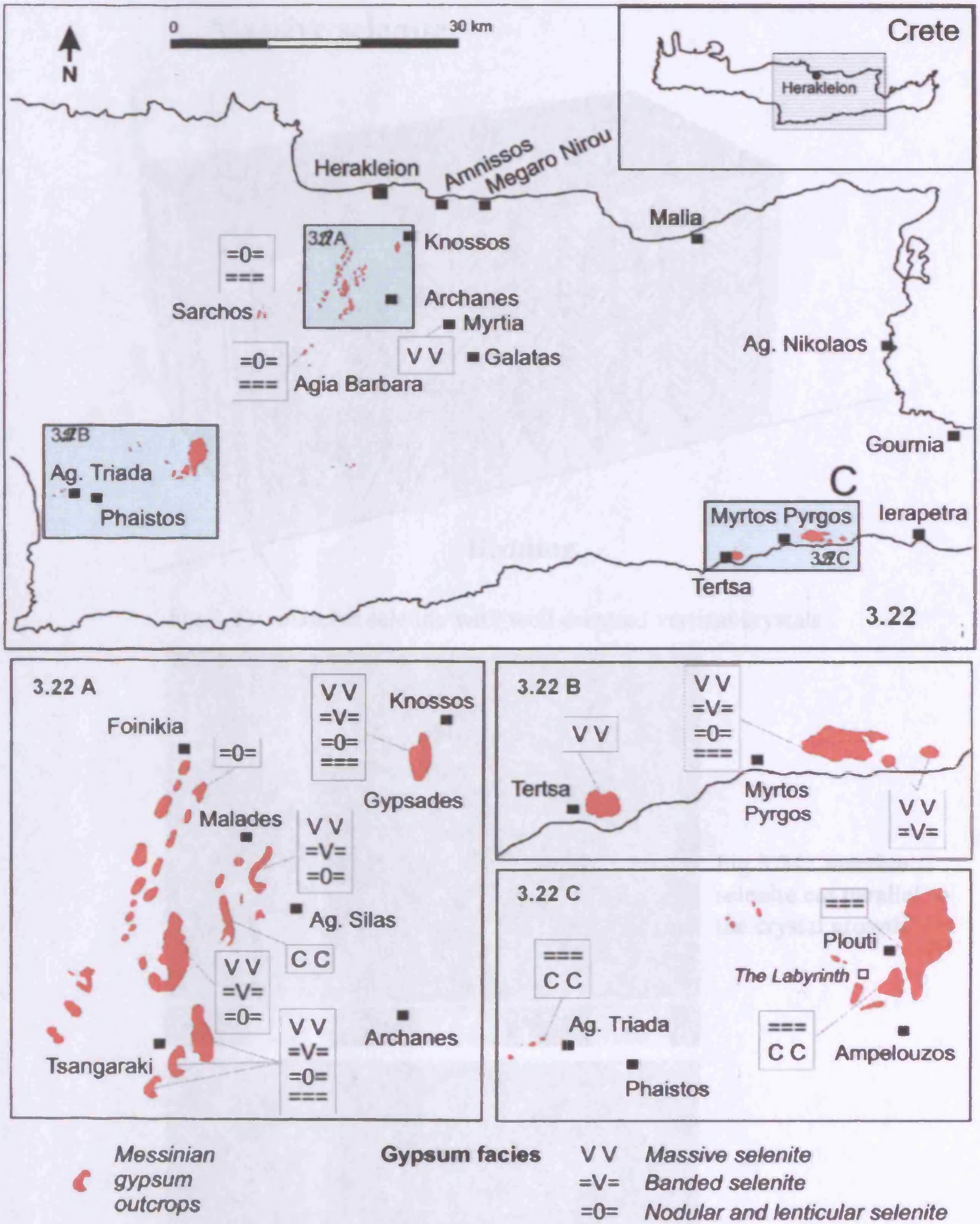


Fig.3.22A-C: Neogene outcrops of gypsum located close to the five archaeological sites that were studied

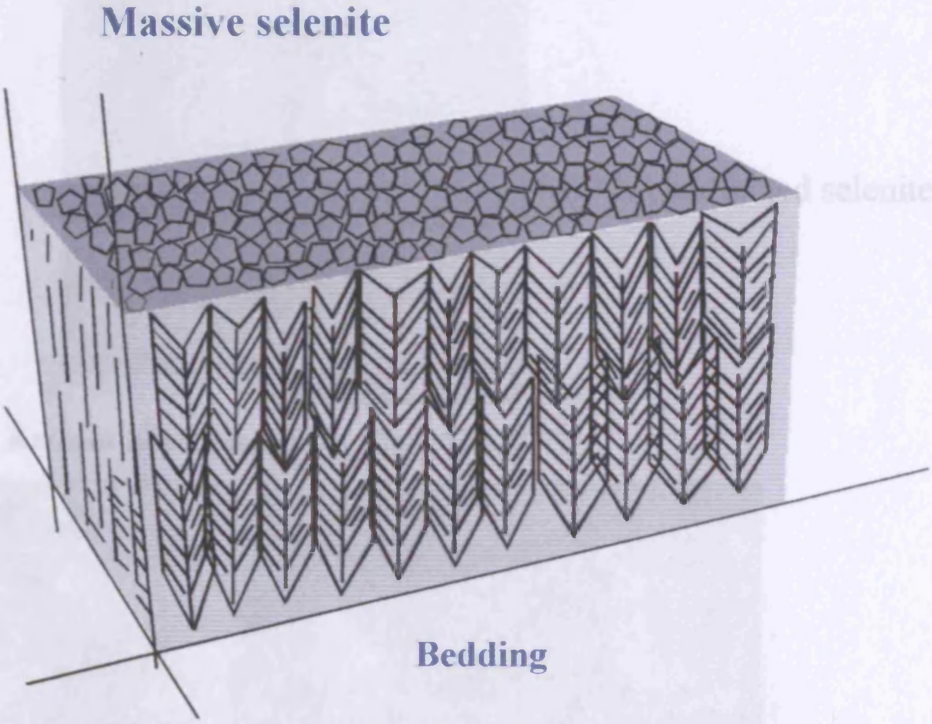


Fig.3.23: massive selenite with well oriented vertical crystals

Fig.3.24: massive selenite cut parallel to the crystal growth

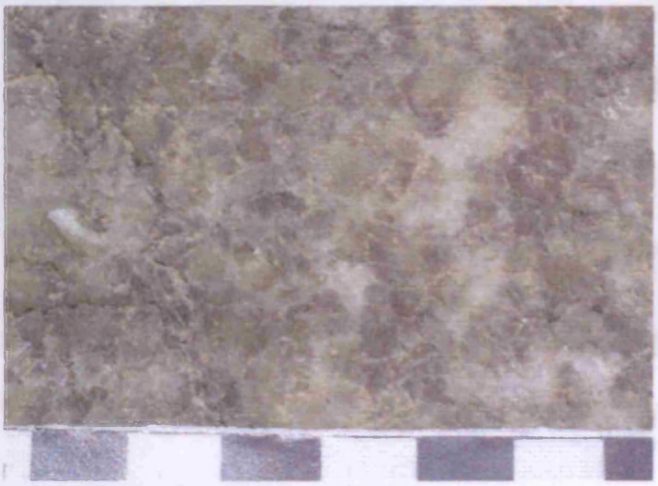
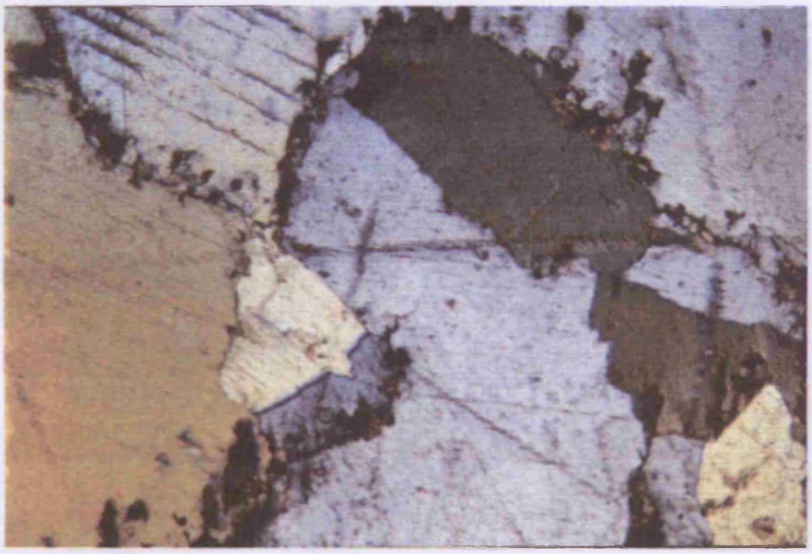


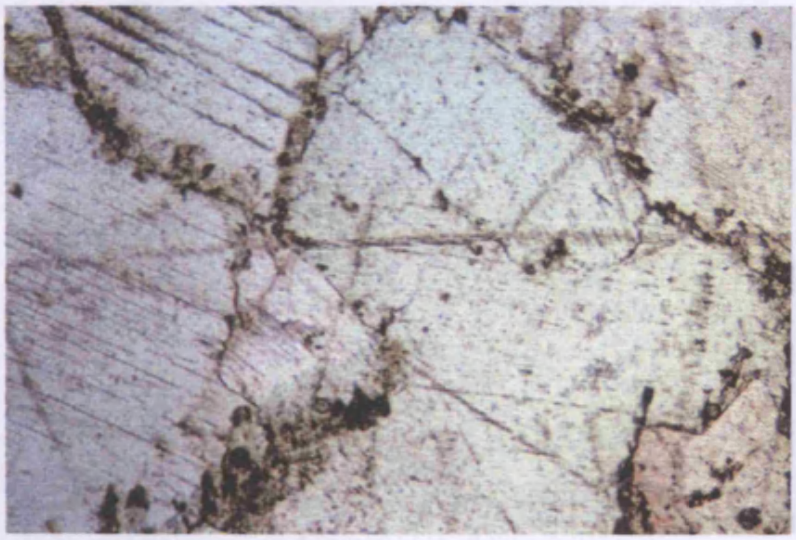
Fig.3.25: massive selenite cut vertically to the crystal growth

SC37: Unaffected selenite.

Knossos Royal Magazines, Floor Slab 1072.



SC37: crossed polars 2.5x



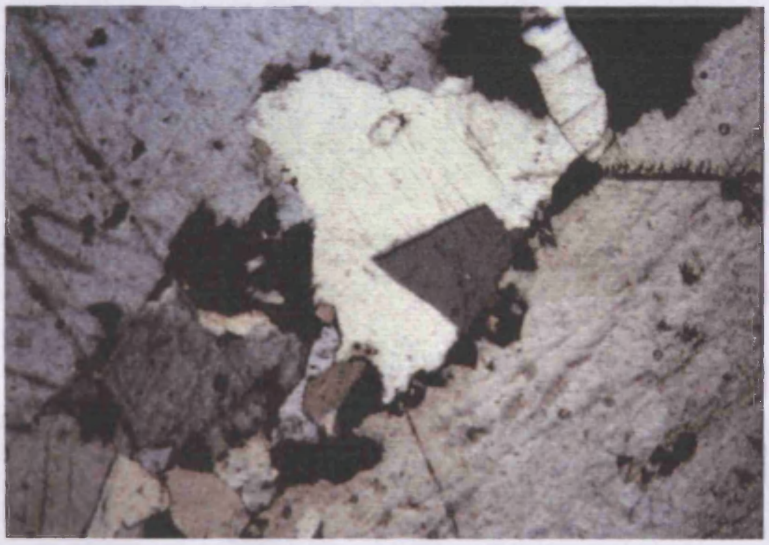
SC37: natural light 2.5x

1 mm

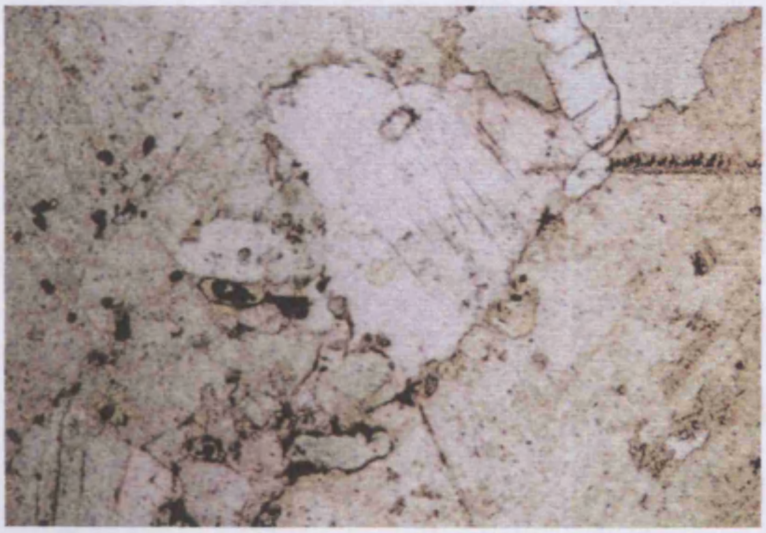
Fig.3.26: unaffected selenite

SC26: Unaffected selenite

Nirou Khani, Room 6, Floor Slab 17



SC26: crossed polars 2.5x



SC37: natural light 2.5x

1 mm

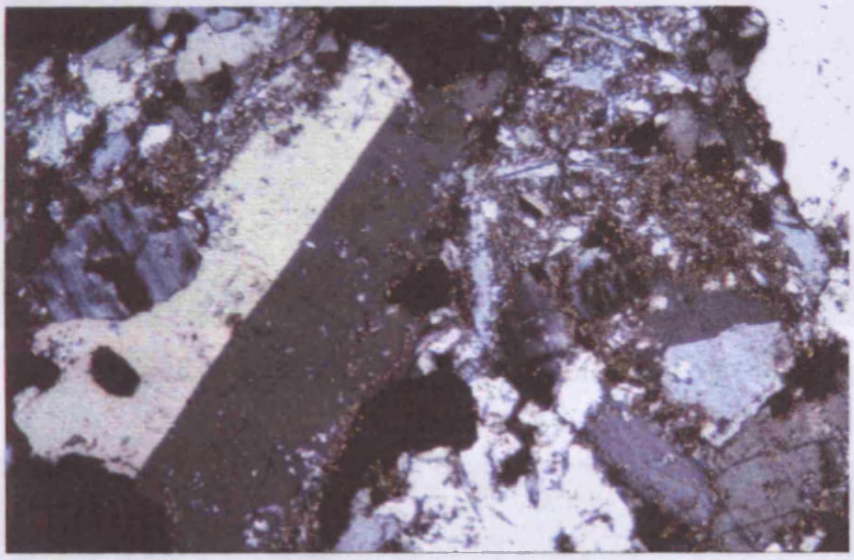
Fig.3.27: unaffected selenite

Fig.38: banded selenite, outcrop of Myrtos

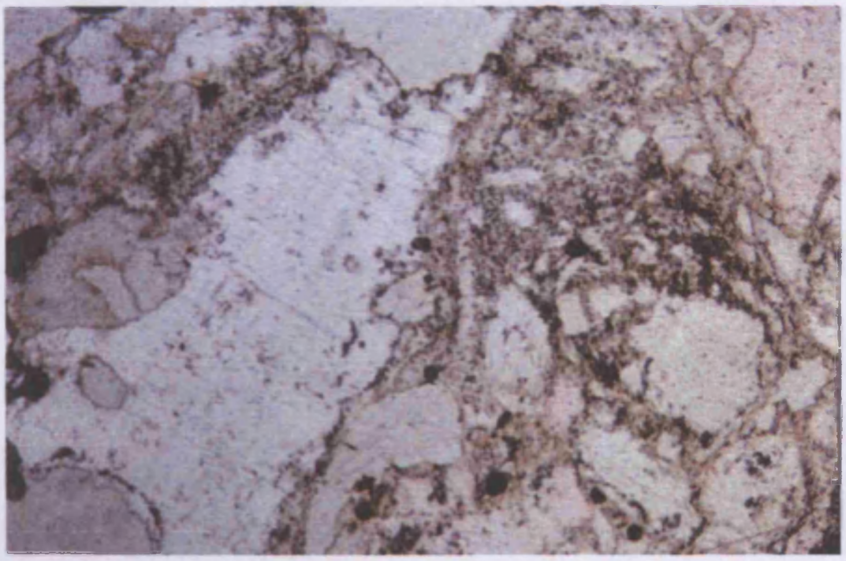
Fig.3.29: banded selenite ashlar blocks, east wall of light-well of Pyrgos

SC41: Unaffected fine selenite. Most crystals appear to be vertical.

Myrtos- Pyrgos, Loose fragment of fine grained selenite .



SC41: crossed polars 2.5x



SC41: natural light 2.5 x.

1 mm

Fig.3.30: unaffected twin crystal

Fig.3.31: nodular and lenticular selenite, outcrop of Sarchos-Pyrgou

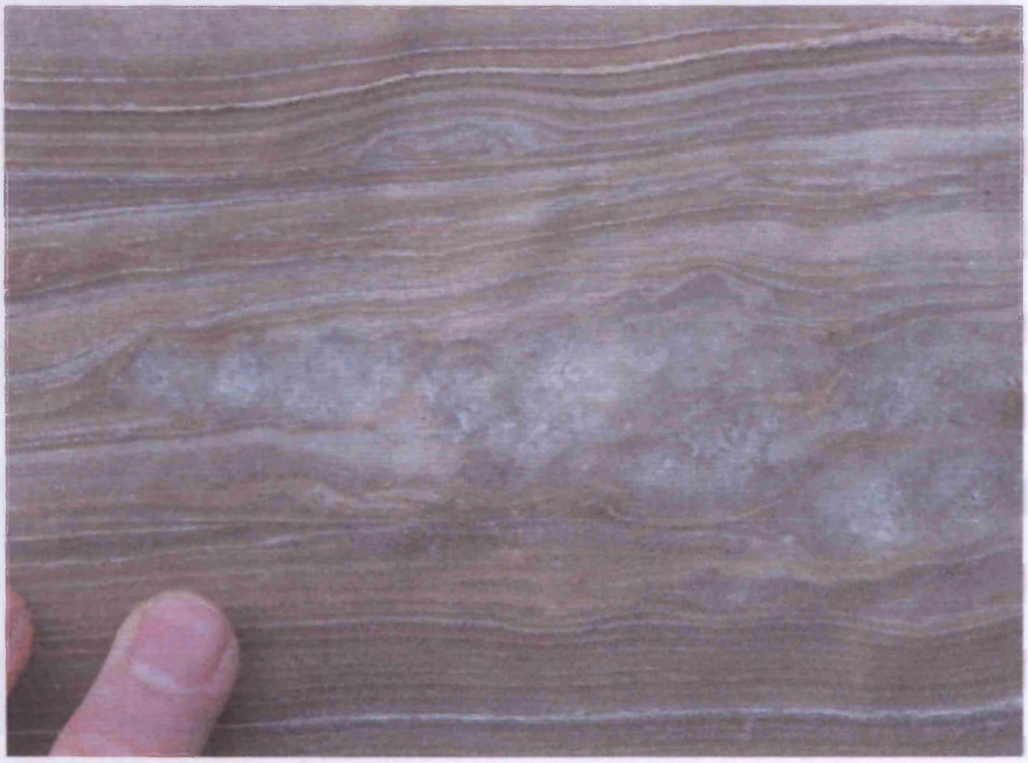


Fig.3.32: lenticular aggregate of clear crystals in nodular and lenticular selenite, detail of previous photo

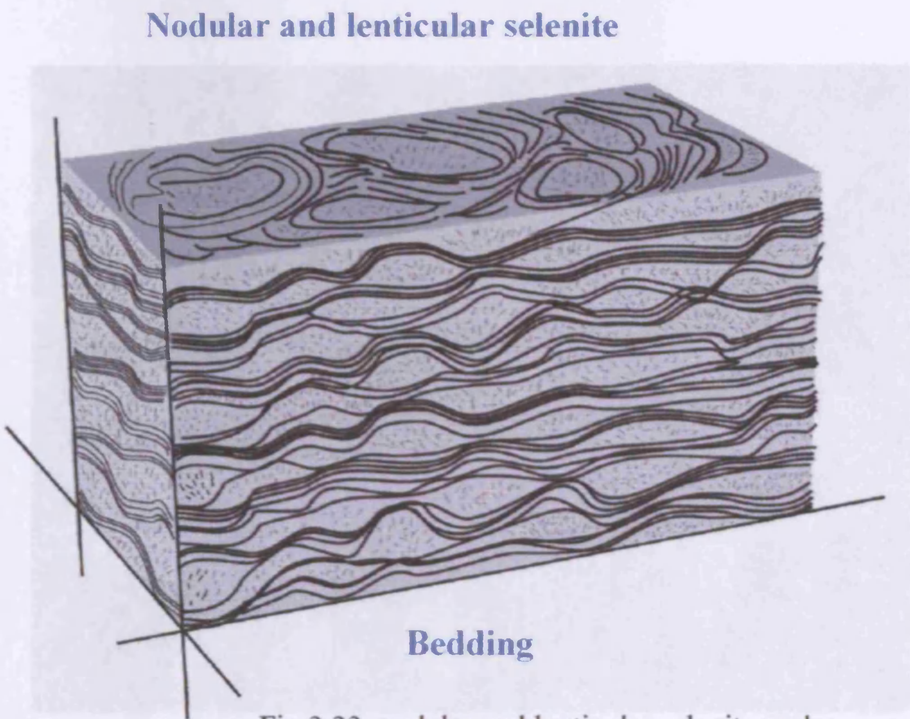


Fig.3.33: nodular and lenticular selenite rock

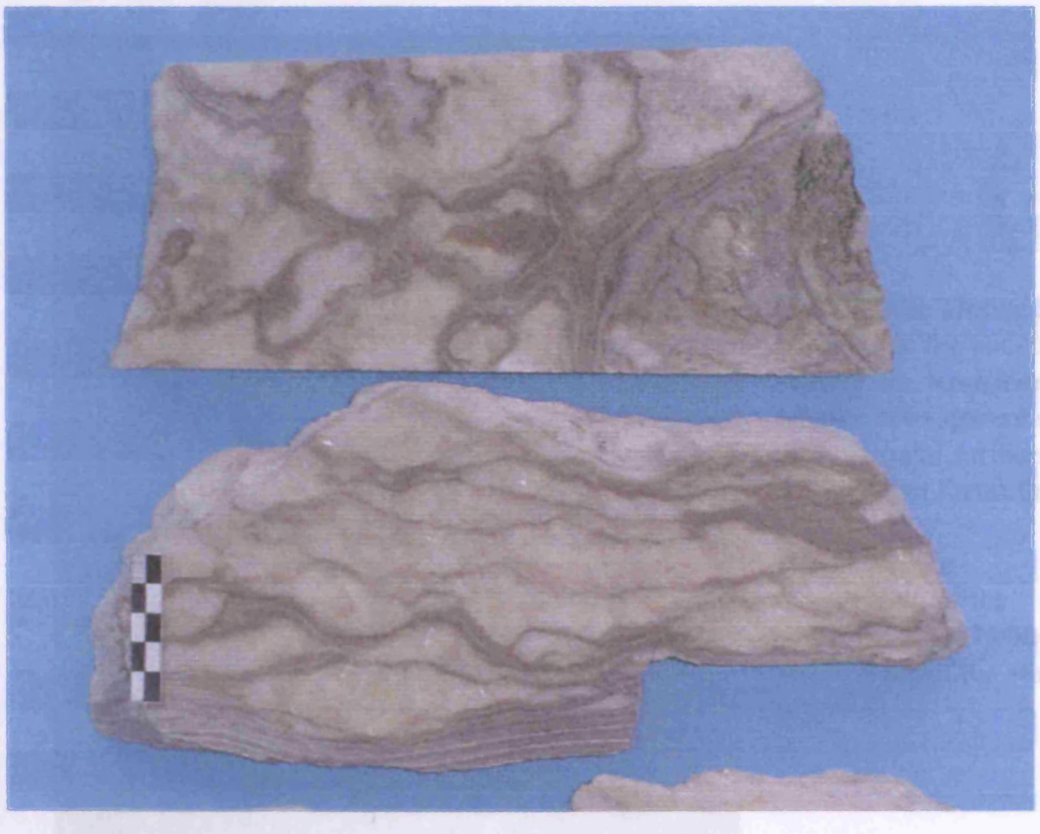


Fig.3.34: the wavy and flaser-like surfaces of nodular and lenticular selenite rock as observed in two sections of the same block

Fig.3.35: naturally separated blocks and slabs of nodular and lenticular gypsum, Foinikia

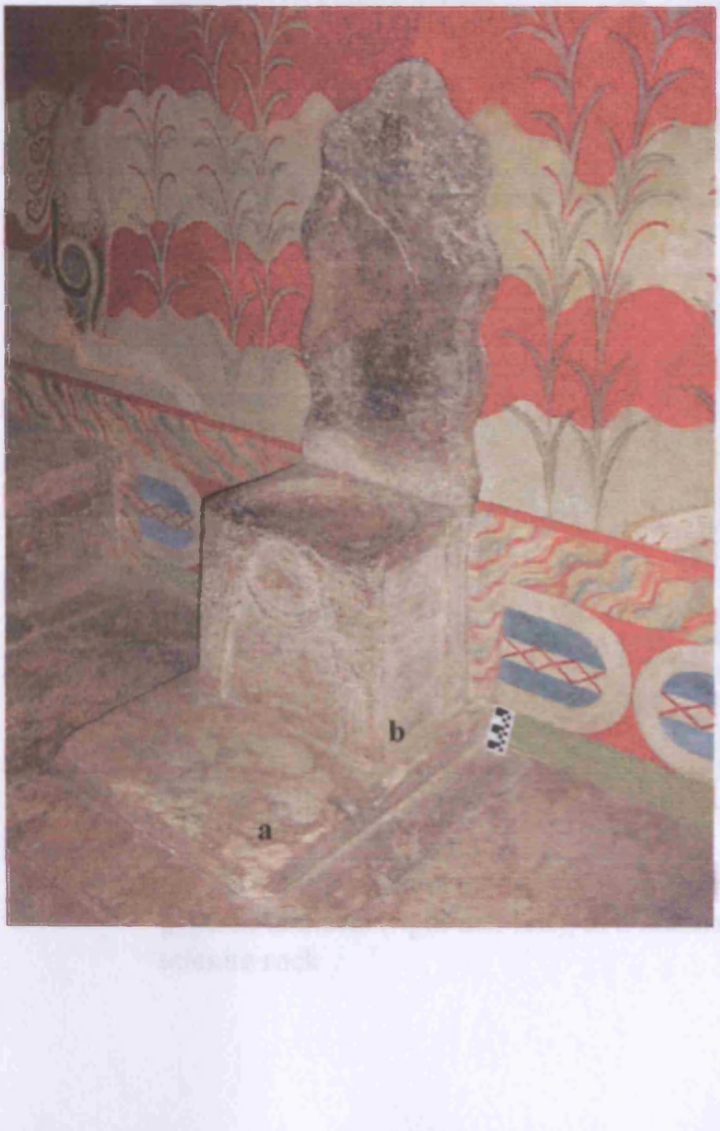
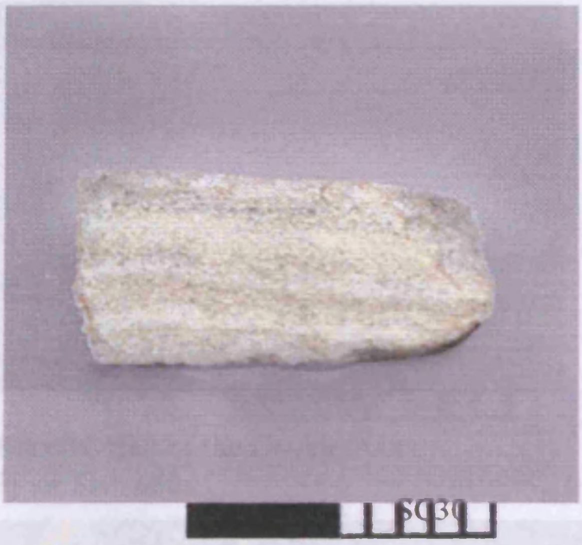
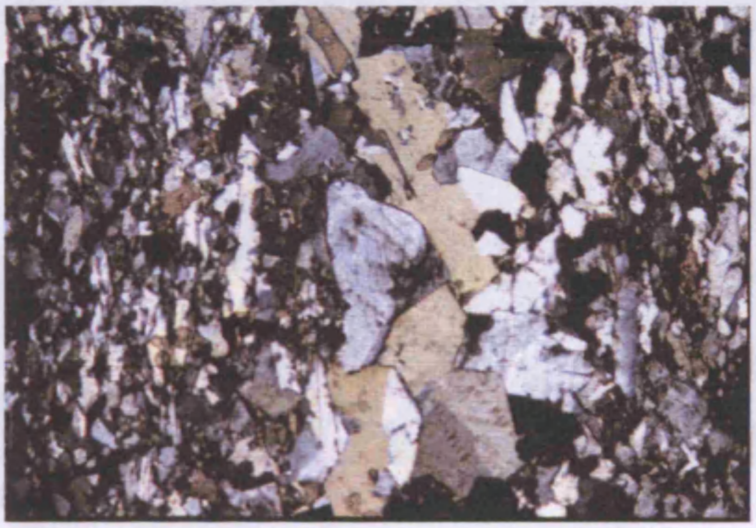


Fig.3.36: the Throne Seat at Knossos: the nodules of nodular and lenticular selenite are apparent on the horizontal surface of the slab that forms the base (a).
The flaser-like arrangement of the laminations can be seen on the sides of the seat (b)

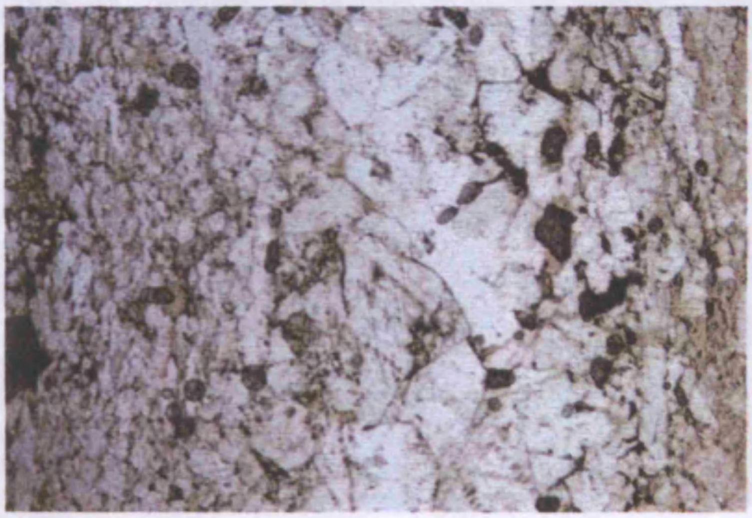


SC30: Unaffected laminated part of nodular and lenticular selenite with layer of elongated twin crystals, some of which are marked on the photo.

Knosos, E-W Corridor, Floor Slab 1006.



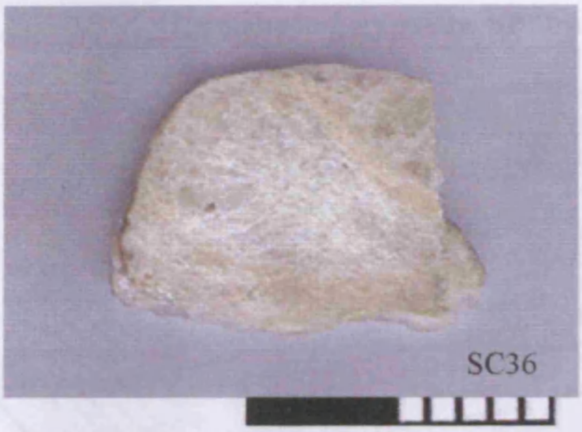
SC30: crossed polars 2.5x



SC30: natural light 2.5x,

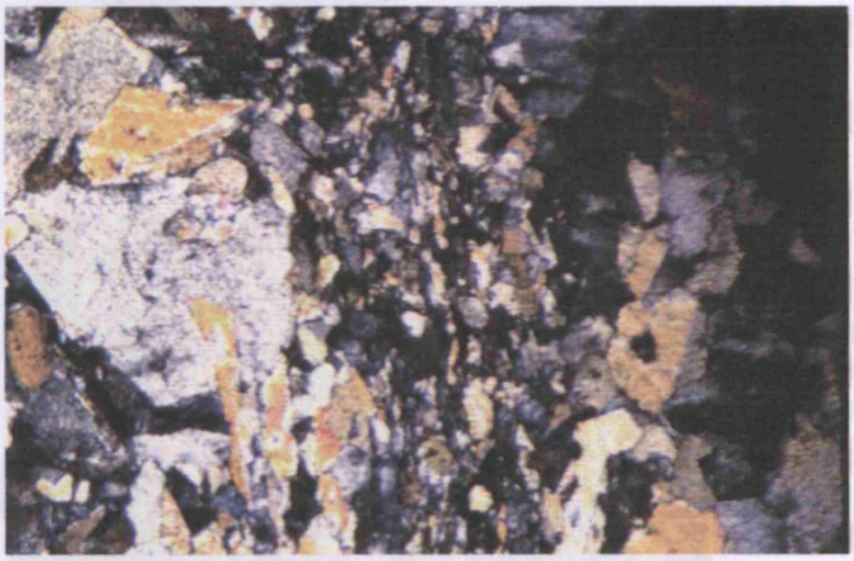
1 mm

Fig.3.37: large selenite crystals at the center enclosed into a gypsum laminite (right and left), in a nodular and lenticular selenite rock

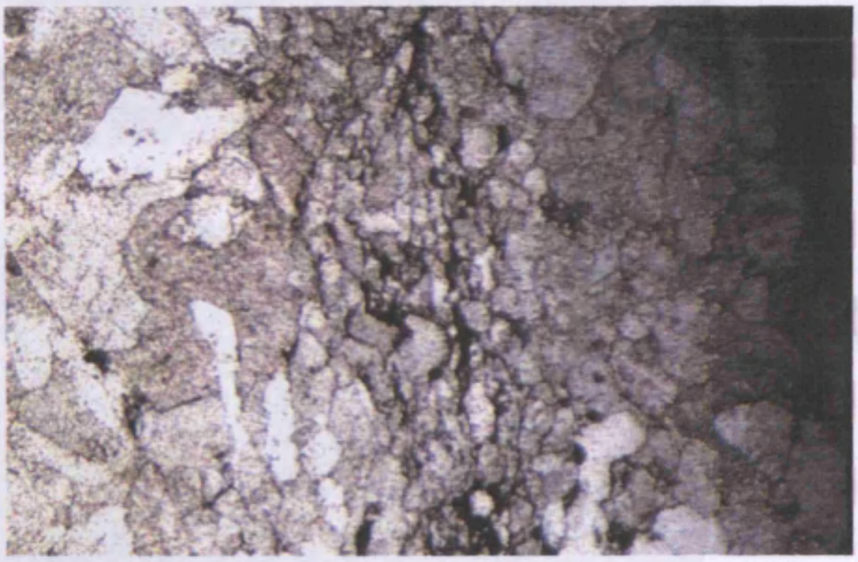


SC36: Unaffected nodular and lenticular selenite rock

Knosos, Hall of the Double Axes,
Floor Slab 666.



SC36: crossed polars2.5x



SC36: natural light 2,5x.

1 mm

Fig.3.38: laminated part of nodular and lenticular gypsum and selenite crystal in the nodules or lenses

Laminated gypsum or 'balatino'

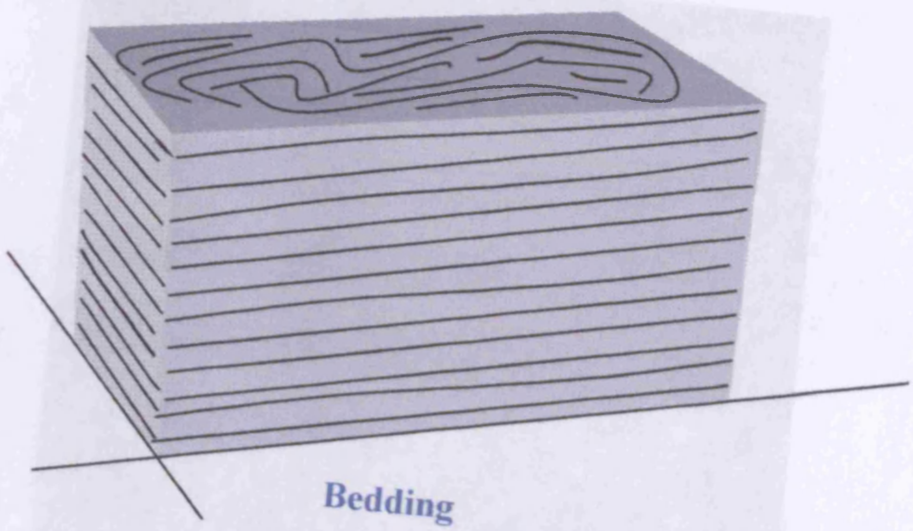


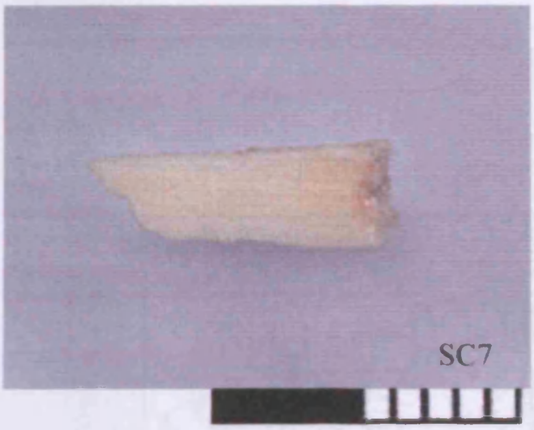
Fig.3.39: laminated gypsum or balatino

Fig.3.40: balatino cut vertically l to the laminations

Fig.3.41: balatino cut parallel to the laminations

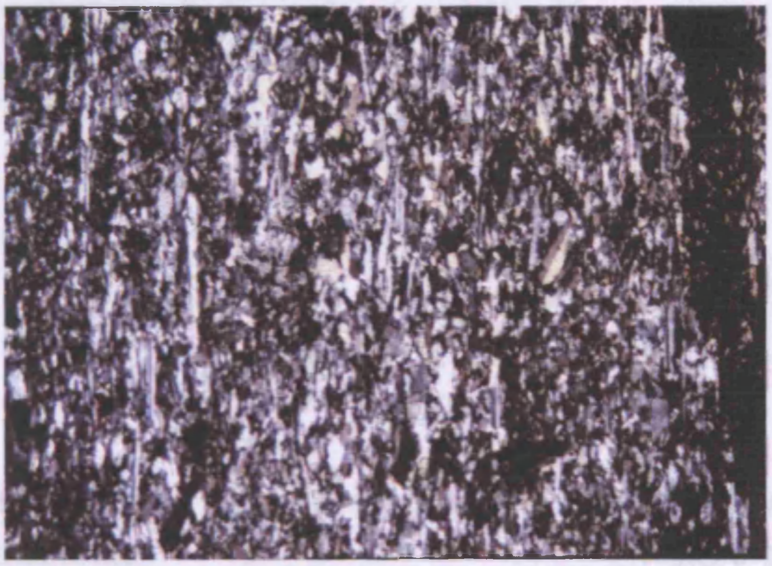
Fig.3.42: laminated gypsum or balatino outcrop, Plouti, Messara

Fig.3.43: naturally separated slab of balatino, Plouti, Messara

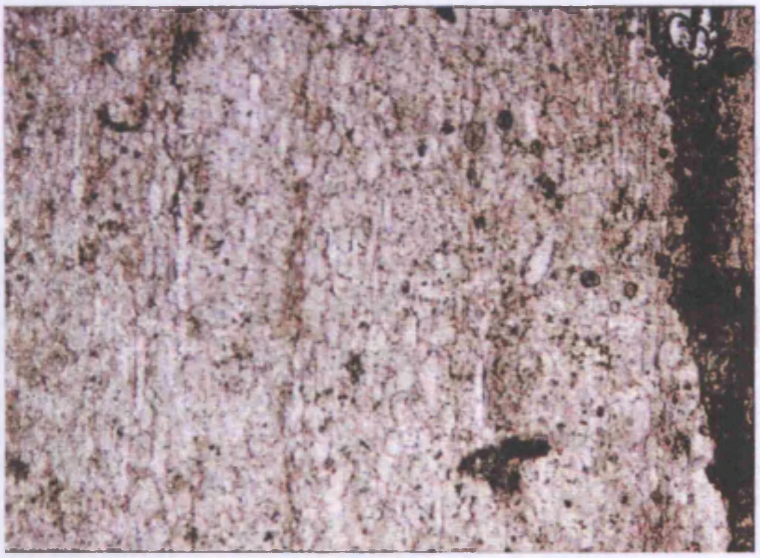


SC7: Messocrystalline idiotopic material with elongated twins crystals (2mm>g >0.06mm). It could be the material from which the structures of the previous samples have derived, after dehydration -rehydration.

Phaistos, Hall 50, Floor Slab 266



SC7: crossed polars, 2.5x



SC7: natural light, 2.5x

1 mm

Fig.3.44: fine grained gypsum laminite consisting of primary twinned gypsum needles

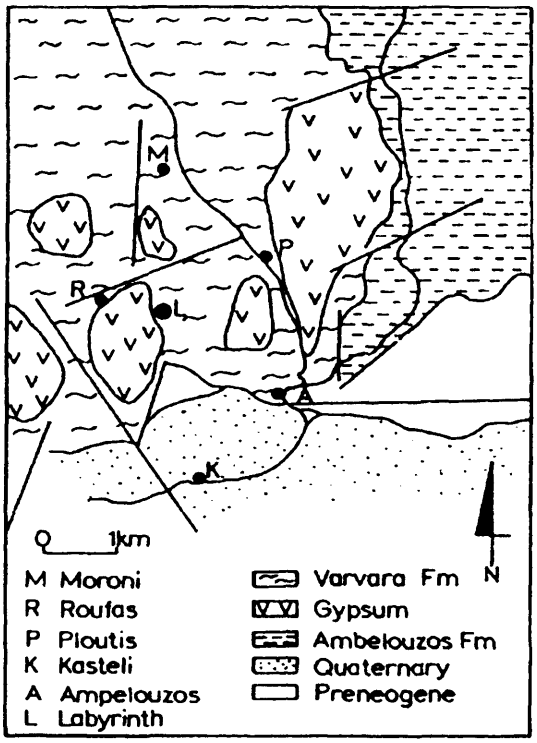
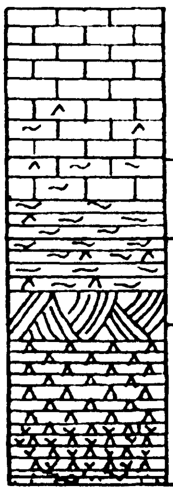


fig.2



STRATIGRAPHIC SEQUENCE		MAIN CHARACTER	DEPOSITIONAL ENVIRONMENT
	UNIT 1 20m	Alabastrine Gypsum	Interidal - Subtidal Supretidal
		Balatino Gypsum	Intertidal - Subtidal
	UNIT 2 3-5m	Selenite	Shallow - Subaqueous
	UNIT 3 5m	Gypsiferous - marl laminities	Shallow - Subaqueous or hypersaline lagoon
	UNIT 4 25m	Carbonates - Tourbidites	Subphotic - Subaqueous

Fig.3.45: evaporitic sequence of the area around the Gortyn cave, after Dermitzakis et al.1990:2052, fig. 2,3

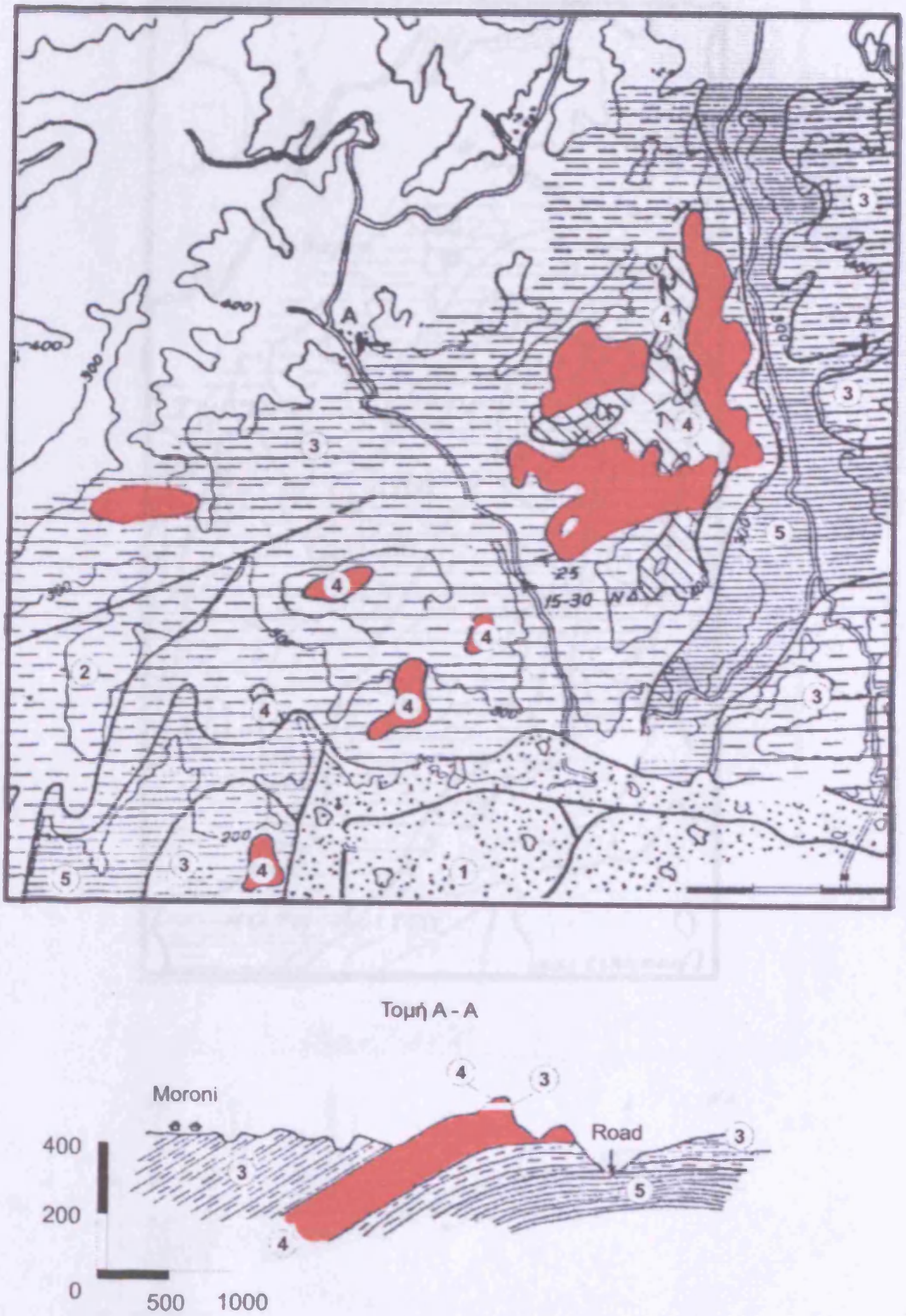


Fig.3.46: gypsum deposits of the Plouti – Moroni –Ambelouzos area, after Kanaris 1989

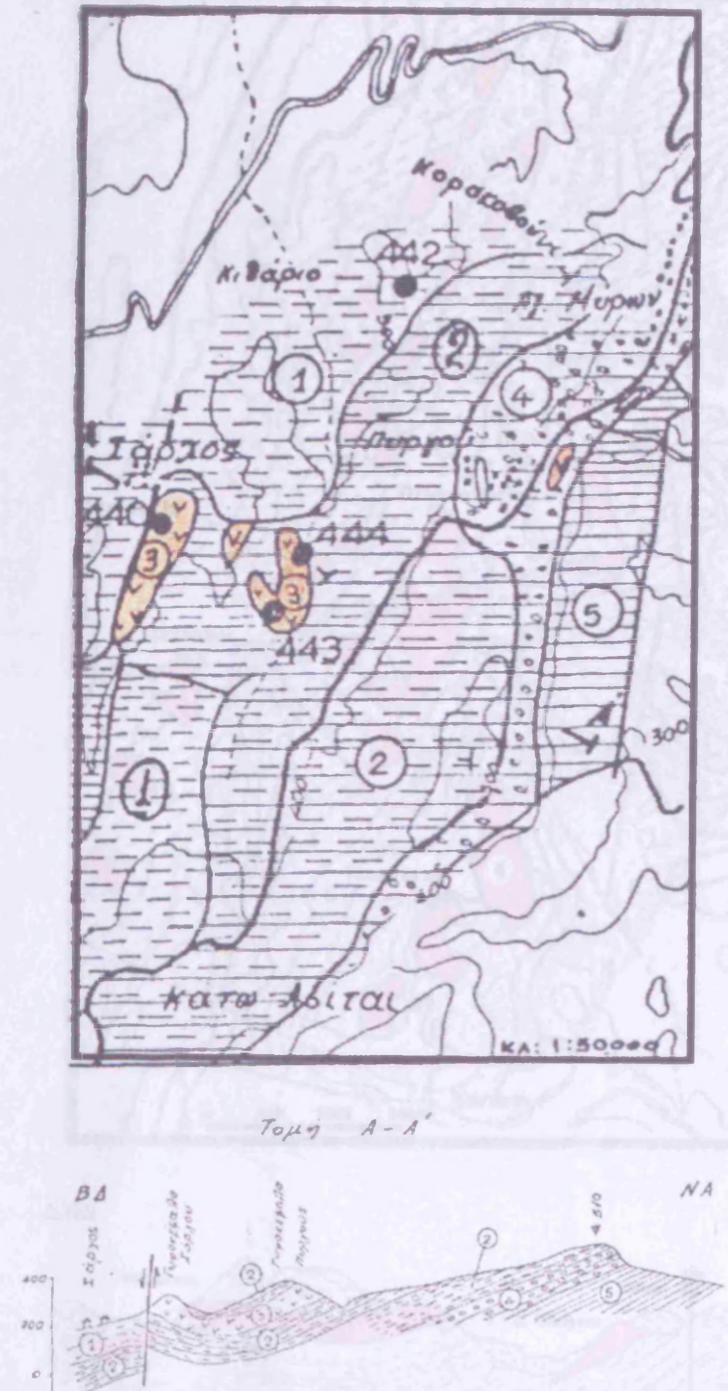


Fig.3.47: gypsum deposits in the area Sarchos–Pyrgou, after Kanaris 1989

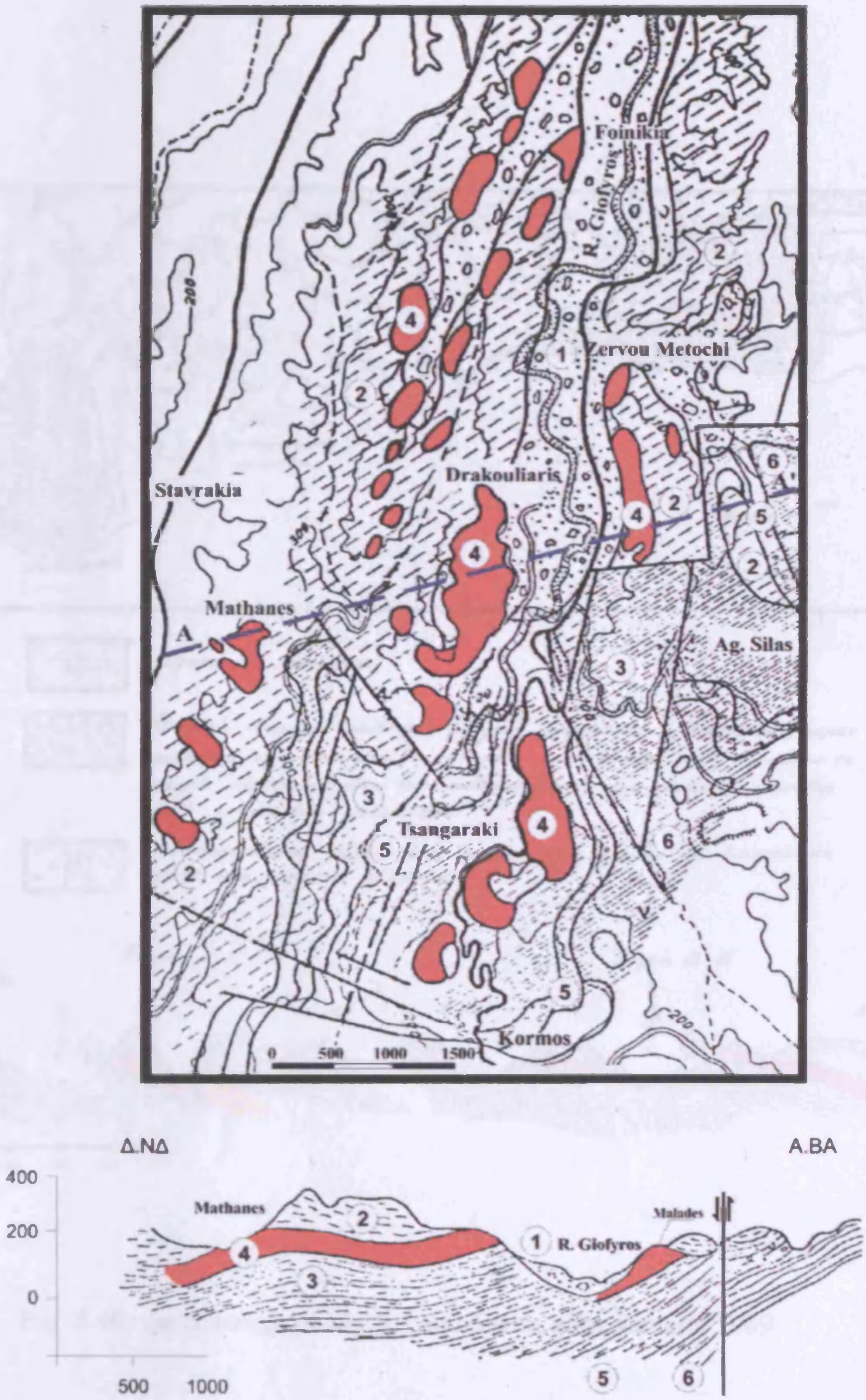


Fig.3.48: gypsum outcrops of Foinikia, Malades and Tsangaraki, south west of Knossos, after Kanaris 1989

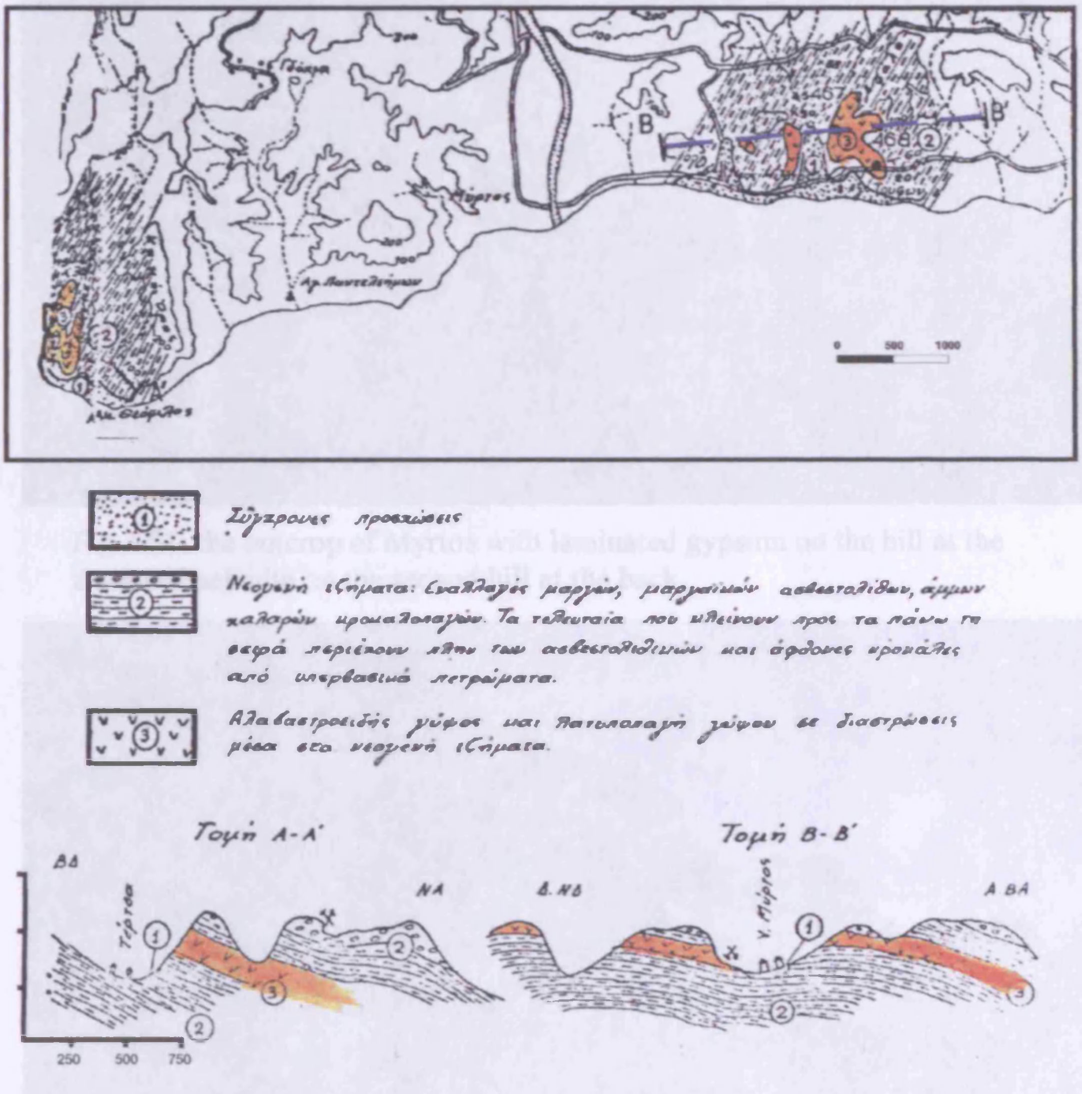


Fig. 3.49: the outcrops of Myrtos and Tertsa after Kanaris 1989

Fig.3.51: the outcrop of Myrtos with laminated gypsum on the hill at the front and selenite on the second hill at the back

Fig.3.52: the outcrop of Myrtos with selenite above laminated gypsum

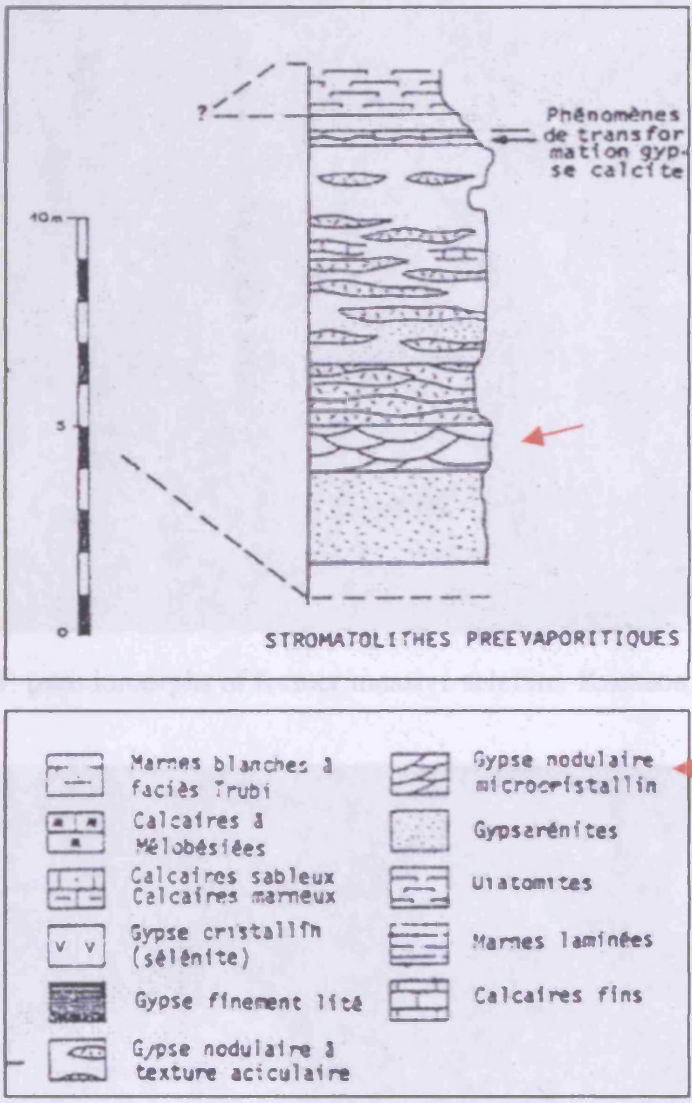


Fig.3.52: stratigraphic columns of the evaporitic sequence at Agia Barbara south of Heraklion, after Rouchy 1982:125, fig.39

Fig.3.53: pseudomorphs of former massive selenite, Knossos, Magazine VII

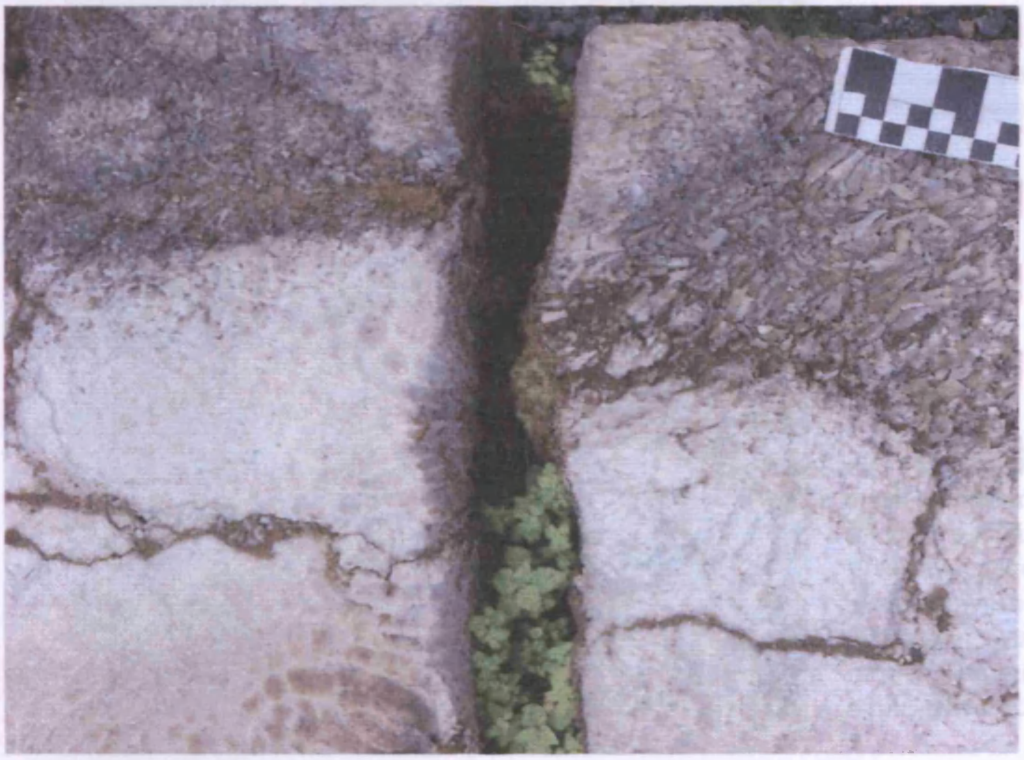
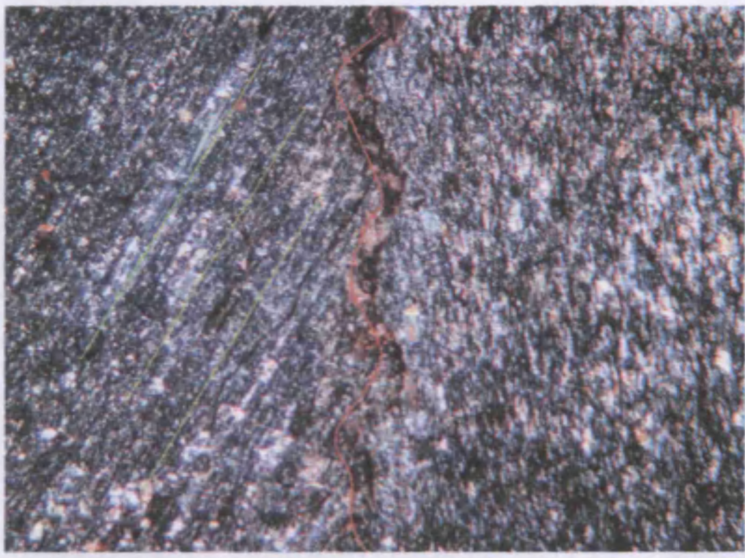


Fig.3.54: partly affected selenite blocks, Knossos, North Lustral Basin

Sample 18: Pseudomorphs after selenitic crystal of which we can see distinctive structural characteristics such as the former cleavage planes and the step shaped crystal boundaries. Dehydration and re-hydration of the sample has resulted in a re-crystallization of the material in a granular microcrystalline structure. The secondary crystals are oriented along parallel lines that resemble the cleavage planes of the original selenitic crystal and correspond to their step shaped edges.

Nirou Khani, Loose Slab 418.



Step shaped crystal boundary
Former cleavage planes

SC18: crossed polars 2,5x.

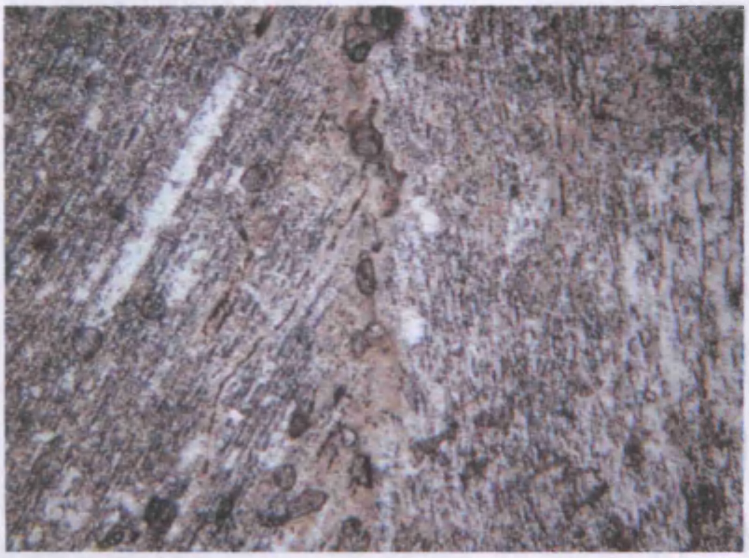


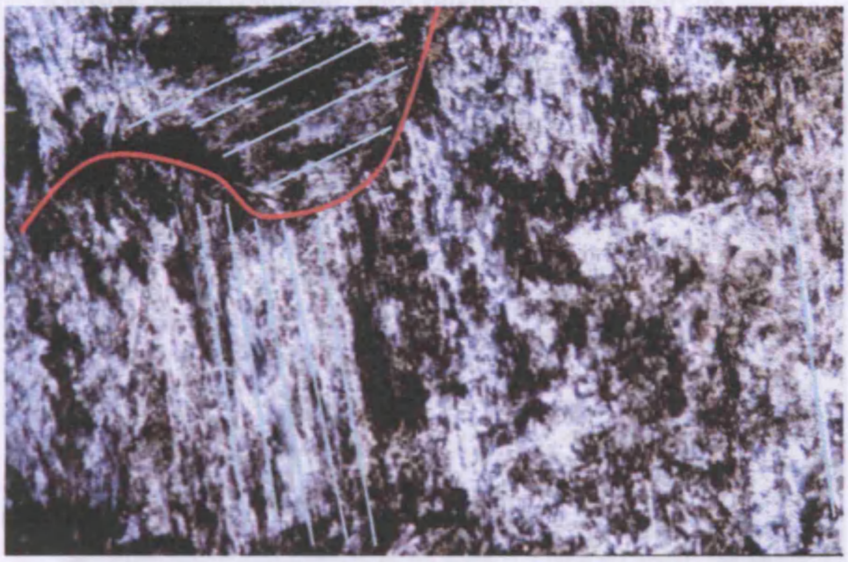
Fig.3.55: stepped shape crystal boundaries in selenitic pseudomorph. Elongated cloudy ameboid gypsum crystals are marking the former cleavage planes of the selenite crystal

SC18: natural light 2,5x.

1 mm

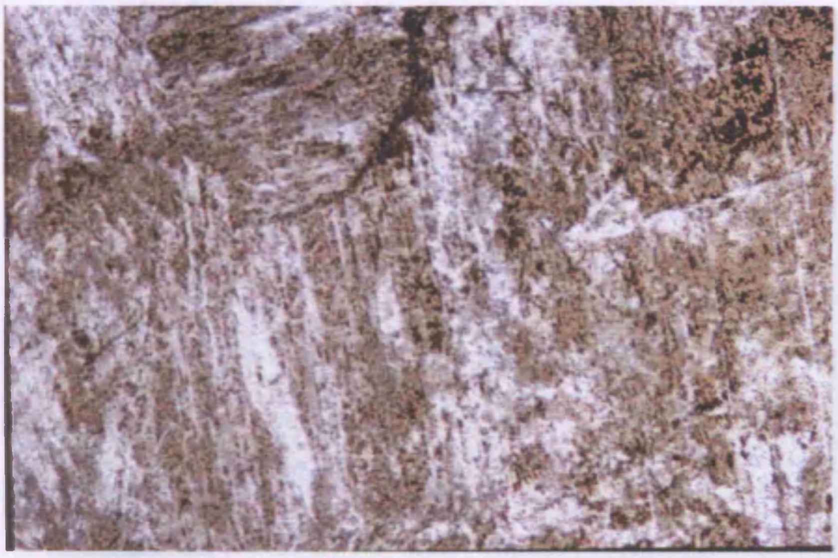
Knossos, Royal Magazines,
Floor Slab 1057.

SC32: Pseudomorph after selenite, of which we can see some of the former crystal's cleavage planes. The present texture of the sample is ameboid with elongated crystals. The elongation of the ameboid crystals follows the former crystal cleavage planes. Microcrystalline carbonates also present in the sample.



SC32: crossed polars 2,5x.

Step shaped crystal boundary
Former cleavage planes

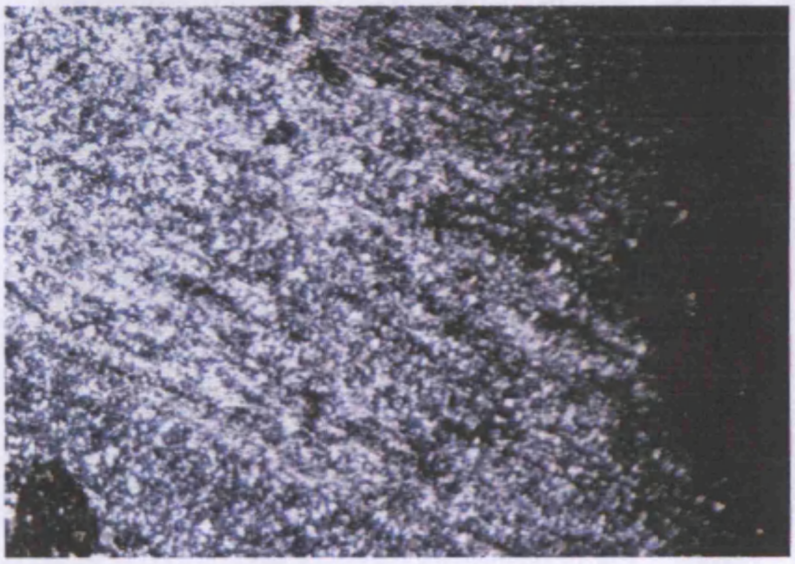


SC32: natural light 2,5x. Dehydrated selenite.

1 mm

Fig.3.56: selenite pseudomorph

Knosos, loose fragment, with selenitic pseudomorphs



SC45: crossed polars 2,5x.

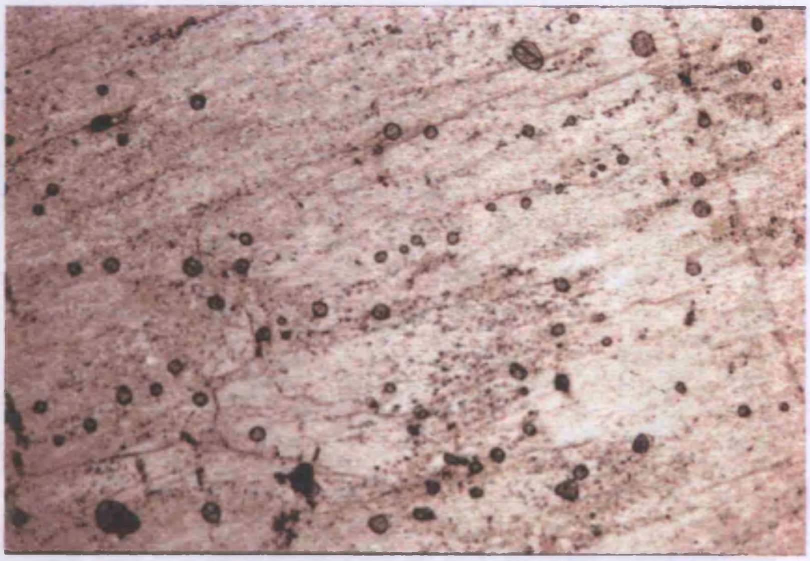
Fig.3.57: detail of selenite pseudomorph, showing the cleavage of the former crystal

SC45: natural light, 2.5x.

1 mm

Sample 19: elongated ameboid gypsum crystals well oriented resembling former cleavage plains of a former single arrow head crystal. A nodule of chalcedony also present in the sample.

Nirou Khani, Threshold 232



SC19: crossed polars 2.5x.

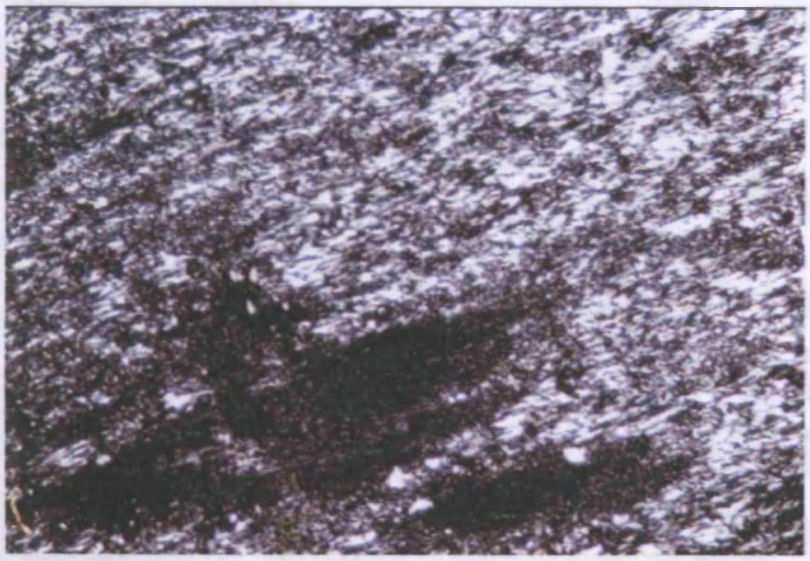


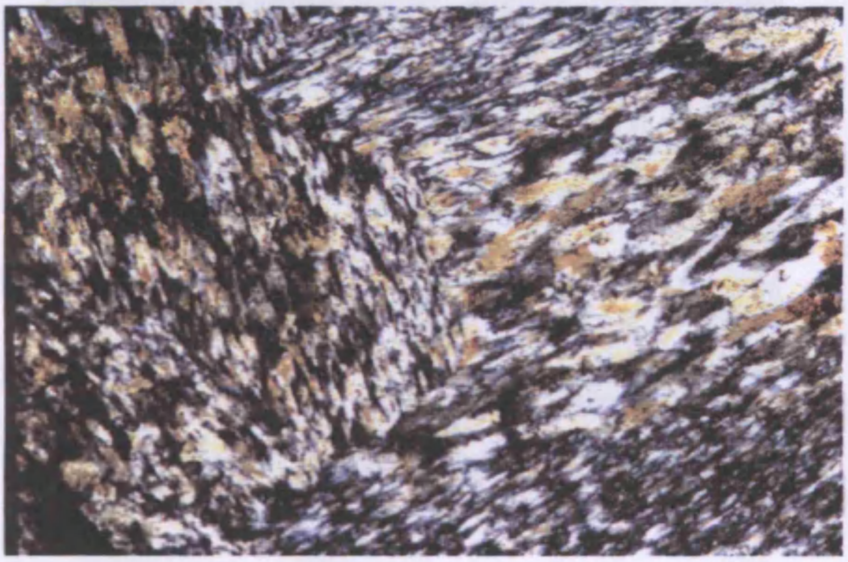
Fig.3.58: large crystal with fibrous texture, probably pseudomorph after selenite

SC19: natural light 2.5x.

1 mm

Nirou Khani, Loose Slab 262.

SC22: Mesocrystalline ameboid gypsum, derived from dehydration/re-hydration of nodular and lenticular selenite rock. Twin crystal ghosts are visible. Clay particles in between the crystals are probably responsible for the gray coloring of the sample.



SC22: crossed polars 2,5x.

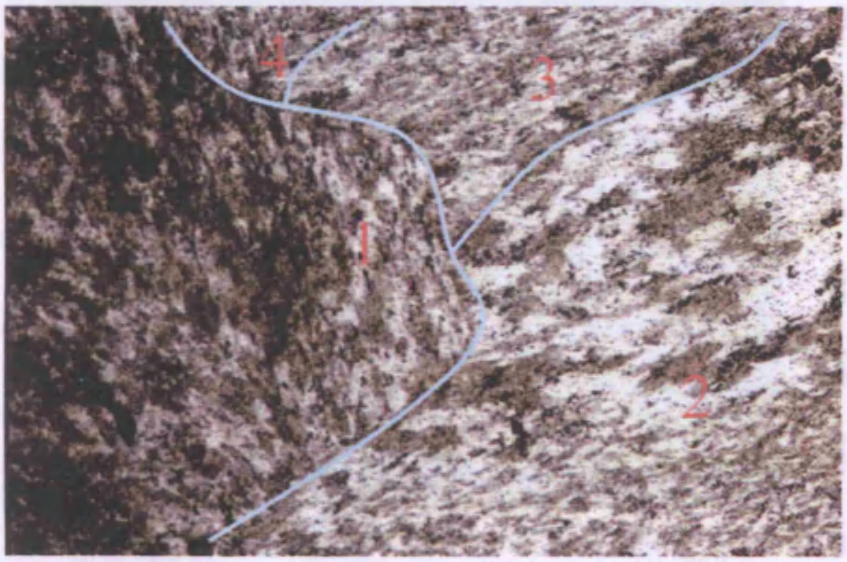


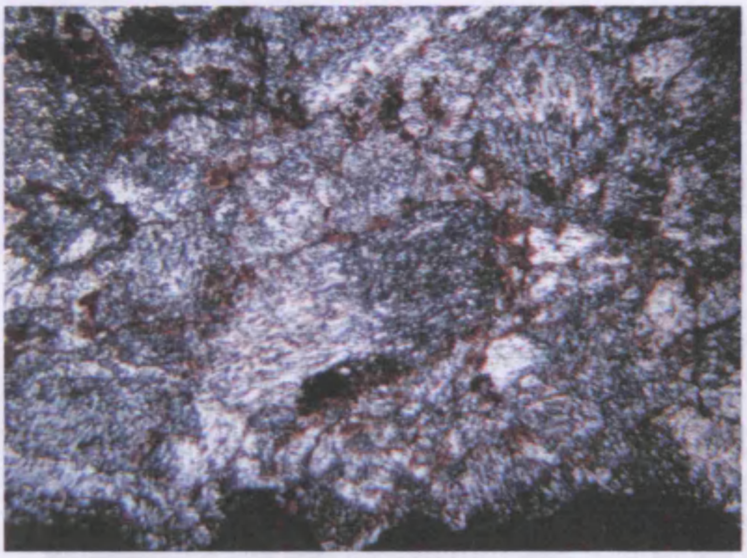
Fig.3.59: pseudomorphosed selenite, boundary of four former selenitic crystals

SC22: natural light 2.5x.

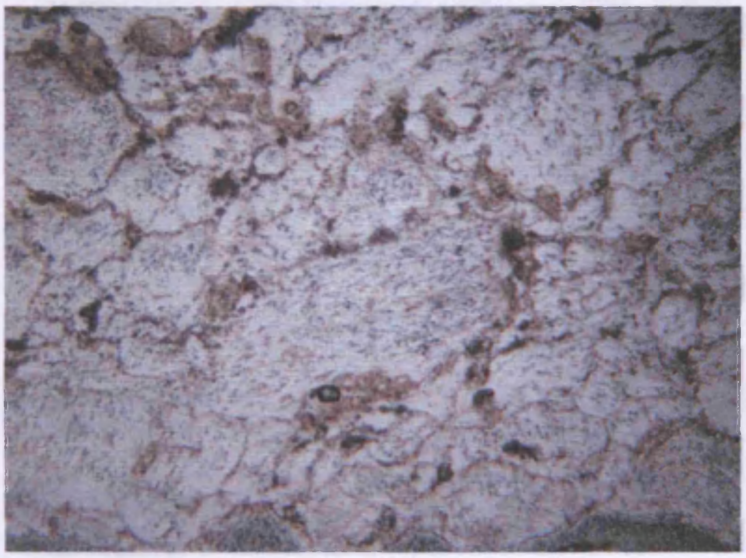
1 mm

SC40: Microcrystalline elongated ameboid gypsum, which resulting from dehydration/re-hydration of an originally banded selenite. Pseudomorphosed features of the former crystals are visible (step shaped crystal boundaries). Voids distributed at the crystal boundaries represent dissolved clay filling.

Myrtos - Pyrgos, Loose Slab 634.,



SC40: crossed polars, 2.5x.

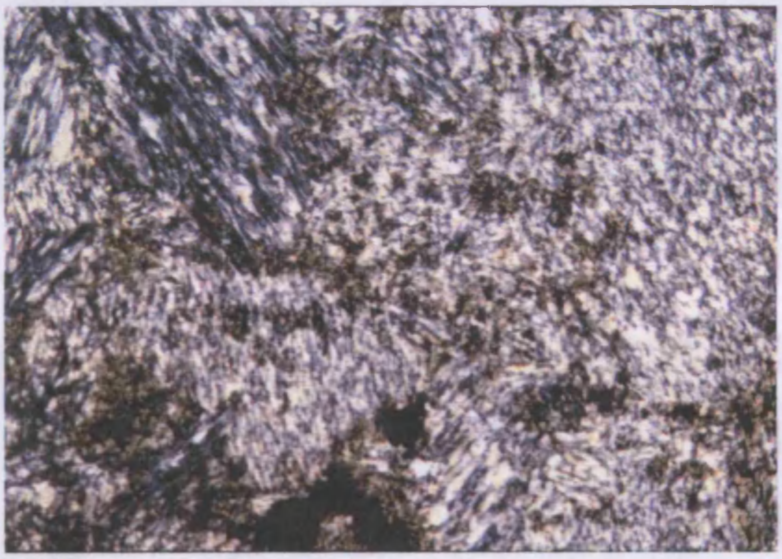


SC40: natural light, 2.5x. 1 mm

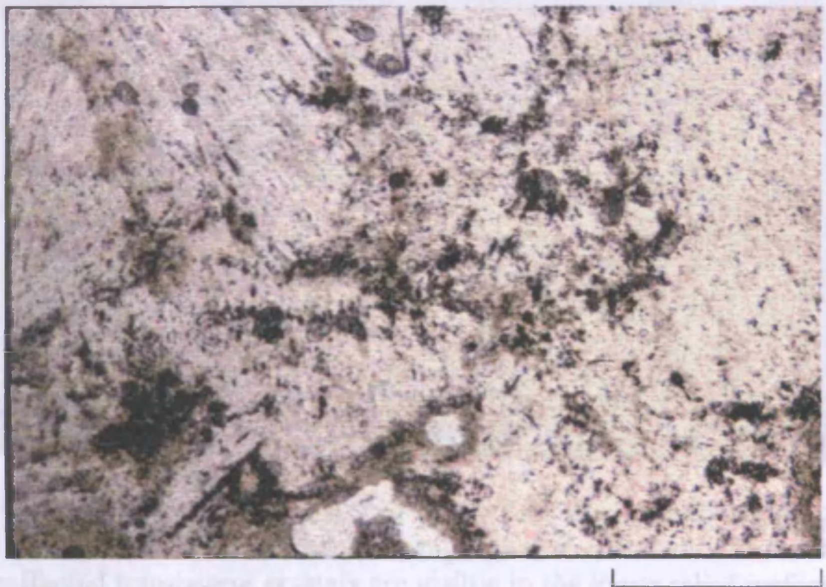
Fig.3.60: step shaped crystal boundaries of pseudomorphosed crystals

SC46: Ameboid microcrystalline gypsum, coming from the dehydration vertical selenite probably banded that is the typical variety of Pyrgos

Myrtos - Pyrgos, Loose Slab



SC46: crossed polars 2,5x.



SC46: natural light 2,5x.

1 mm

Fig.3.61:ameboid texture of selenite pseudomorphs

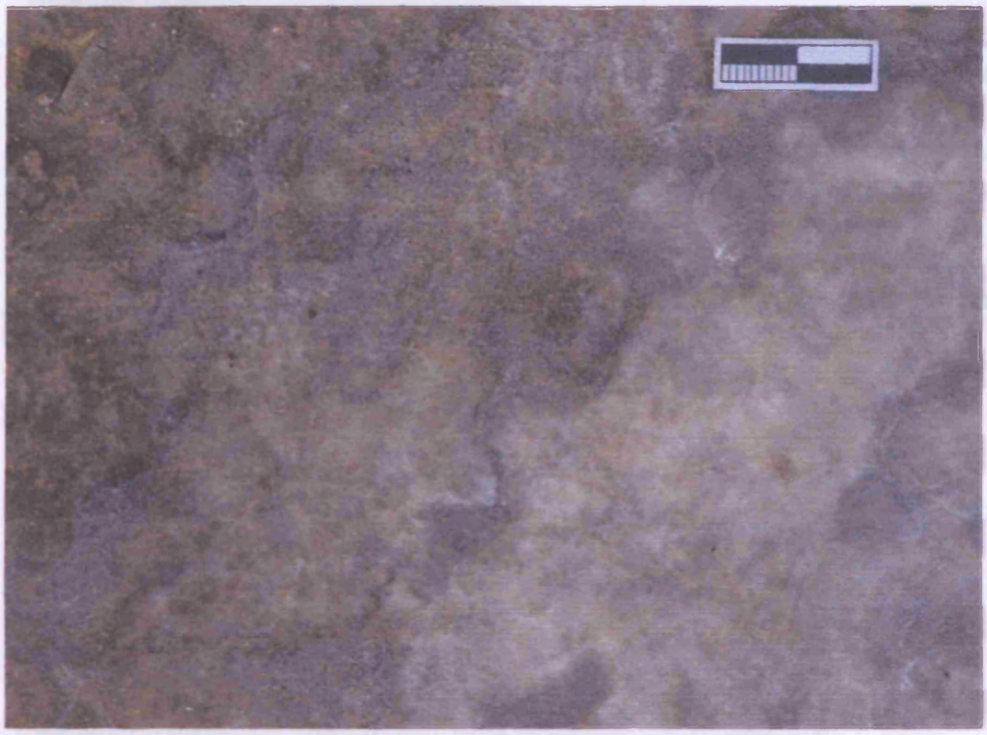
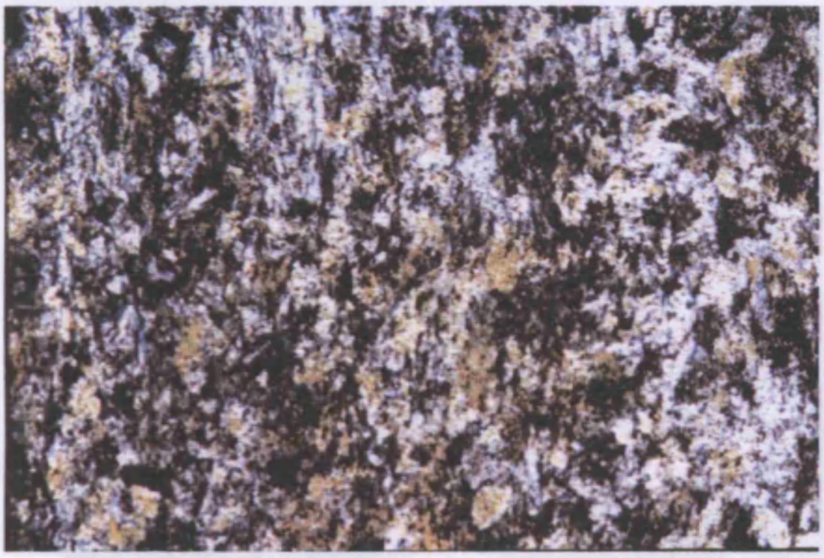


Fig.62. selenite pseudomorphs in the lenses of nodular and lenticular selenite, floor slab at Hall 2, Megaron Nirou

Fig.3.63: nodular and lenticular gypsum affected by fire: pseudomorphs of selenitic crystals are visible on the white higher relief areas areas of the sample while unaffected transparent crystals are visible in the lower relief surfaces (in the middle) that have been exposed after dissolution of the upper affected layer, doorjamb base at the entrance of the North Lustral Basin at Knossos

SC34: Laminated ameboid gypsum derived from dehydration – hydration of 'ballatino' or laminated part of nodular and lenticular gypsum. We can see some former needles nearly 2mm long. The coloring owes to the presence of clays and possibly the oxidation of pyrite (iron sulfide).

Knossos, Grand Staircase, Tread 501.



SC34: crossed polars 2,5x.

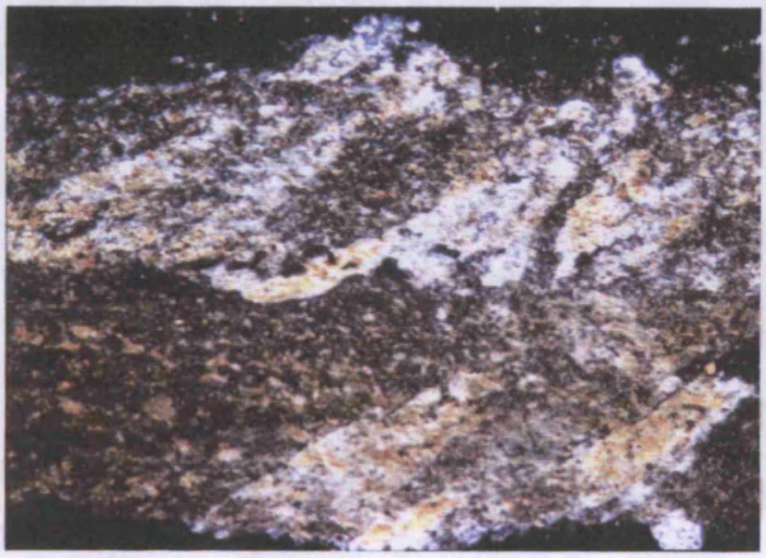
SC34: natural light 2,5x.

1 mm

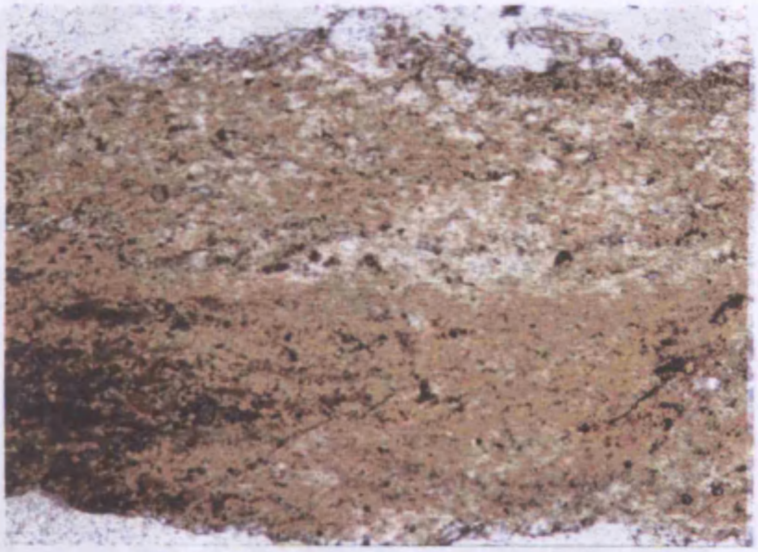
Fig.3.64: affected balatino or nodular and lenticular selenite

SC35: Elongated ameboid crystals comprised by former 'ballatino' like needles. The sample has undergone dehydration – hydration cycle/s, but this may have happened under natural conditions either at the outcrop or at the building site.

Knosos, grand Staricase, Tread 485.



SC35: crossed polasrs 2,5x.



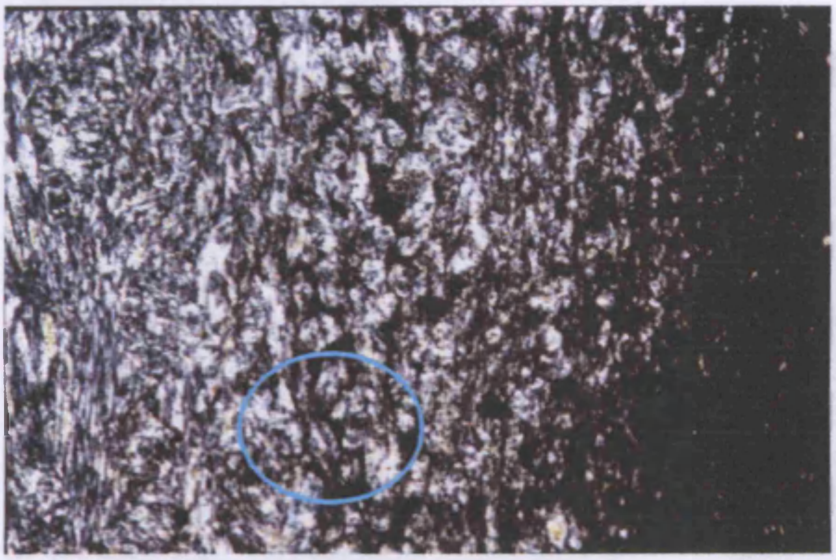
SC35: natural light 2,5x.

1 mm

Fig.3.65: affected balatino

SC23: Graded bedding which varies from mesocrystalline to macrocrystalline. The presence of carbonate matrix makes evident the pseudomorphs of hexagonal crystals (marked in cyrcle on the photos). The hexagonal shapes are now filled with micro-ameboid crystals. The original rock was a nodulare and lenticular selenite

Nirou Khani, Loose fragment of dark gray gypsum.



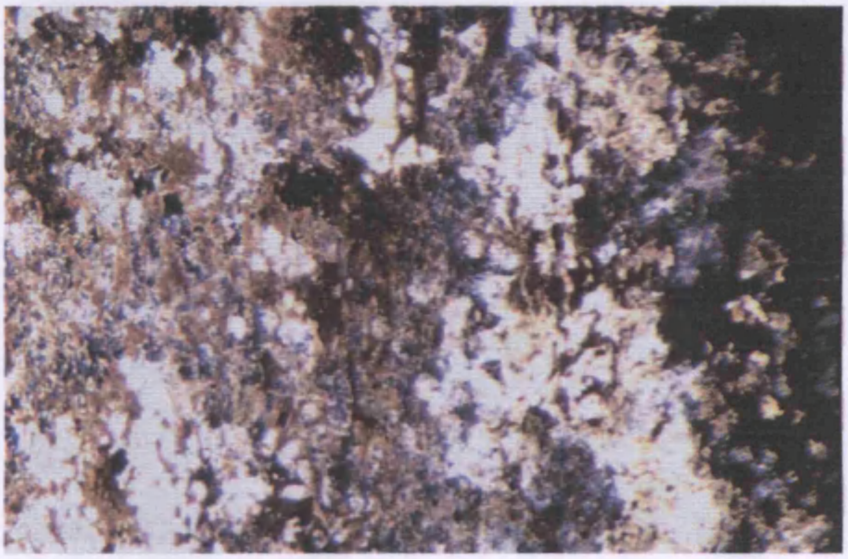
SC23: crossed polars 2,5x.

SC23: natural light 2,5x.General view. 1 mm

Fig.3.66: graded bedding which varies from mesocrystalline to macrocrystalline

SC52: Pseudomorphosed noodular and lenticular selenite rock

Nirou Khani, Loose Slab 302.



SC52: crossed polars 2,5x.

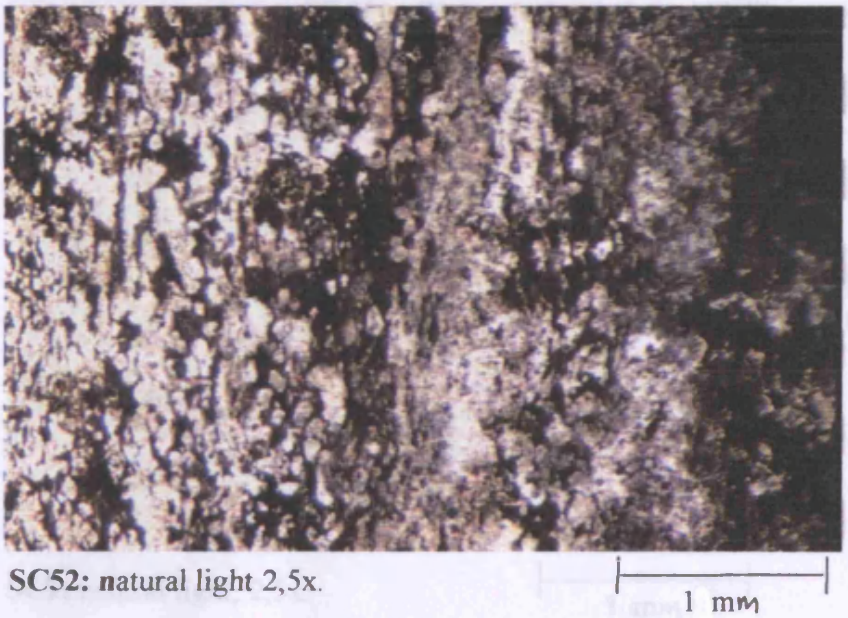


Fig.3.67: clay or carbonate lamination in nodular and lenticular selenite

SC52: natural light 2,5x.

Sample 9: Microcrystalline gypsum with fibrous texture, well oriented. Pseudomorphs after needles also exist. Iron oxides and clays are responsible for the pinkish color of the vein.

Phaistos, Room 7, loose fragment of orange - purple gypsum typical of the colored variety of Messara

SC9: crossed polars 2,5x.

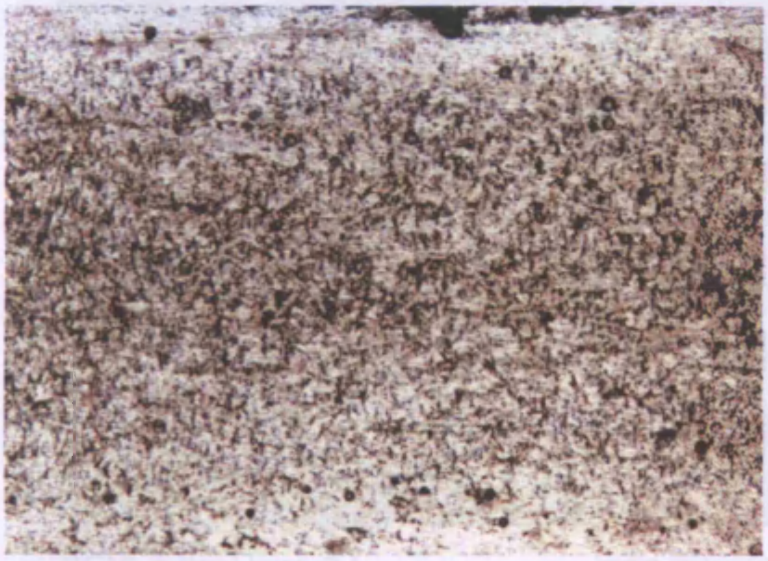
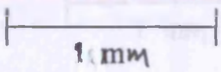


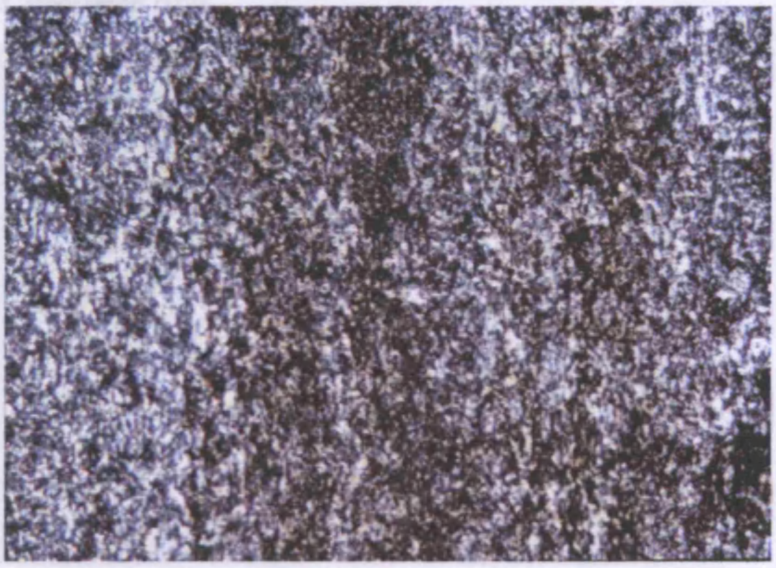
Fig.3.68: lamination with former needles

SC9: natural light, 2,5x.



SC10: Microcrystalline granular gypsum with former needles and clay laminae.

Agia Triada, loose fragment of pinkish gypsum



SC10: crossed polars, 2,5.

Fig.3.69: clay lamination. Some former needles can be traced

SC10: natural light, 2,5.

1 mm

Sample GA1: unaffected selenite rock with well oriented crystals up to 3cm long. Intense dissolution observed in the crystal boundaries. The samples are very similar to the selenite boulders that can be seen on the side of the road on the way to Myrtia about 5 km before the village

Galatas, doorjamb base

GA1: crossed polars,2.5x

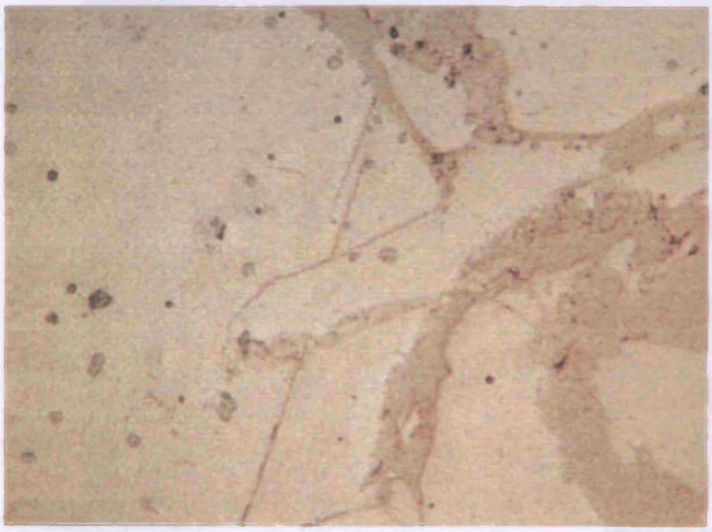


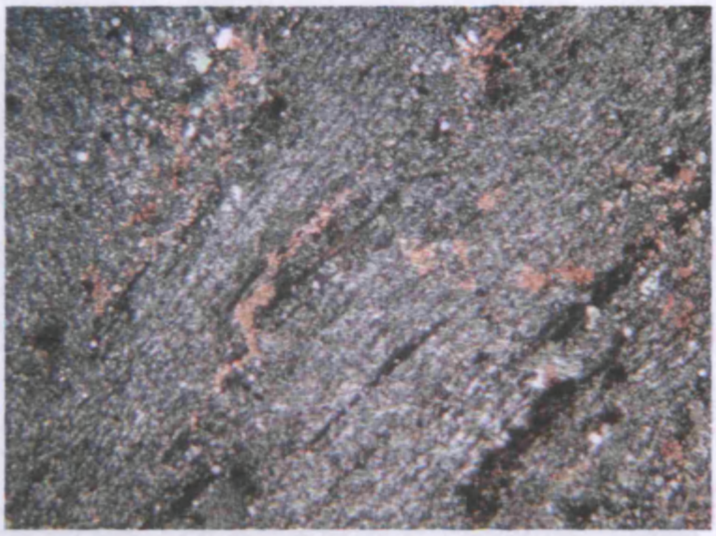
Fig.3.70: vertical selenite with a few faint spaghetti like cyanobacteria filaments and some carbonate. Dissolution is observed along the crystal boundaries

GA1: natural light,2.5x

1 mm

Palaikastro (PK90 ET88E #3473)

Sample PK36: Alabastrine rock derived from dehydration of selenite or the selenite nodules or lenses in a nodular and lenticular selenite. Pseudomorphs are outlined by microcrystalline carbonate seams and parallel elongated cloudy ameboid crystals which mimic selenite cleavage planes. In some parts granular xenotopic gypsum crystals apparently grow at the expenses of cloudy ameboid gypsum.



PK36: crossed polars, 2.5x.

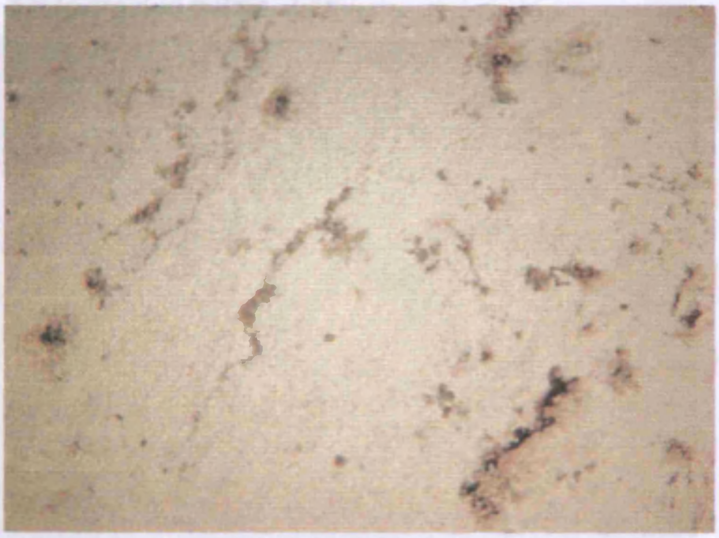


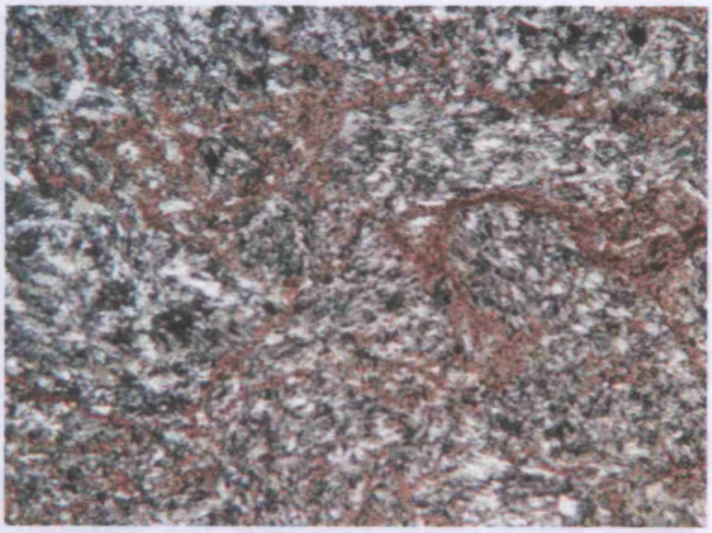
Fig.3.71: elongated ameboid crystals derived probably from dehydration of massive or nodular and lenticular selenite

PK36: natural light, 2.5x.

1 mm

Zakros, doorjamb base, Room F

Sample ZK1: Alabastrine rock derived from dehydration of selenite or the selenite nodules or lenses in a nodular and lenticular selenite. Pseudomorphs are outlined by microcrystalline carbonate seams and parallel elongated cloudy ameboid crystals which mimic selenite cleavage planes. Granular xenotopic gypsum crystals, probably grown at the expenses of cloudy ameboid gypsum, are present as a rare feature.



ZK1: crossed polars, 2.5x.

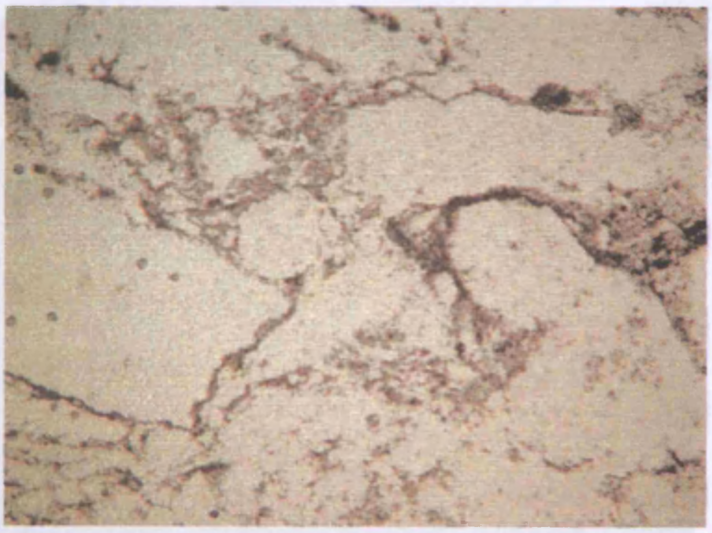


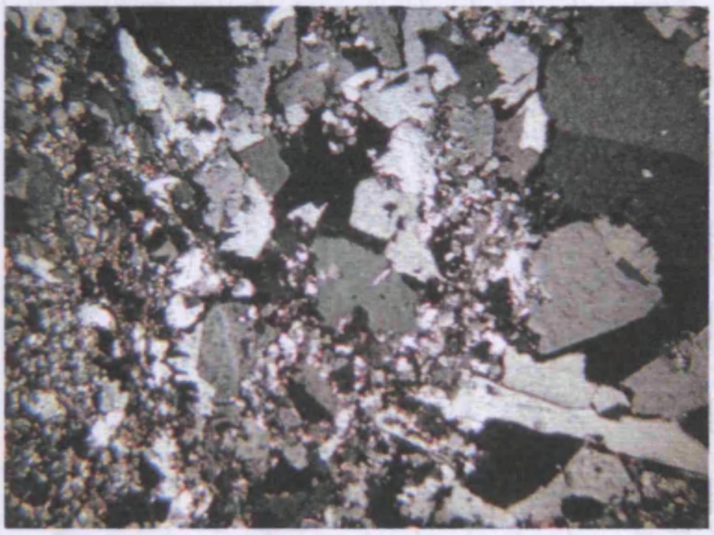
Fig.3.72: elongated and granular cloudy ameboid crystals. Pseudomorphs of selenite are outlined by microcrystalline carbonate. The initial variety is nodular and lenticular selenite

ZK1: natural light, 2.5x.

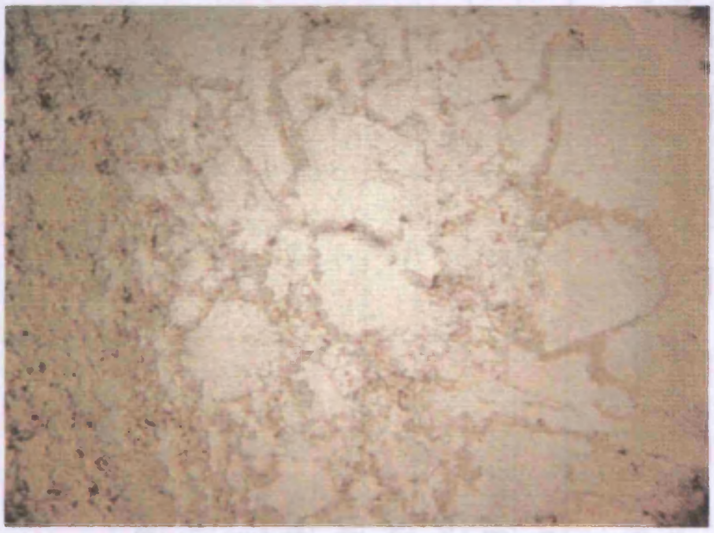
1 mm

Pseira doorjamb, building AQ

Sample PS1: small selenite crystals in the nodules or lenses of nodular and lenticular selenite rock that is weathered due to dissolution along the crystal boundaries



PS1: crossed polars, 2.5x



PS1: natural light, 2.5x.

1 mm

Fig.3.73: unaffected nodular and lenitcular selenite

Site	Number of Samples	Selenites	Massive	Banded	Nodular and Lenticular	Laminated or Balatino	Dehydration Features	Unidentified
Knossos	18	14	10		4	4	15	
Phaistos	11					9	9	2
Agia Triada	6					6	5	1
Megaron Nirou	11	9	6		3	2	10	
Pyrgos	7	7		7			6	
Galatas	2	2			2			
Zakros	2	2			2		2	
Palaikastro	2	2			2		2	
Pseira	2	2			2			

Table 3.5: summarised conclusions of the petrographic study of sixty-one thin sections of Minoan gypsum. The unidentified samples consist of mesocrystalline of microcrystalline granular textures and may be part of a laminated gypsum rock but the sections are too small to allow the accurate identification of the variety

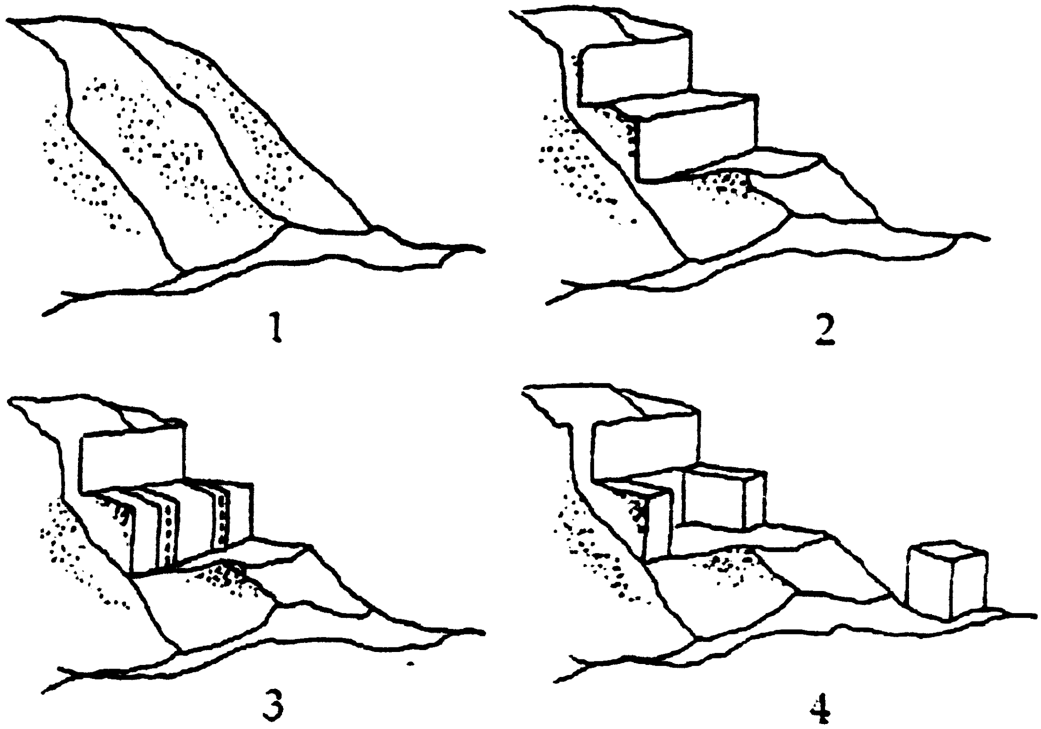


Fig.4.1: quarrying stages in stepped structures, after Rockwell (1993:161, drawing 52)

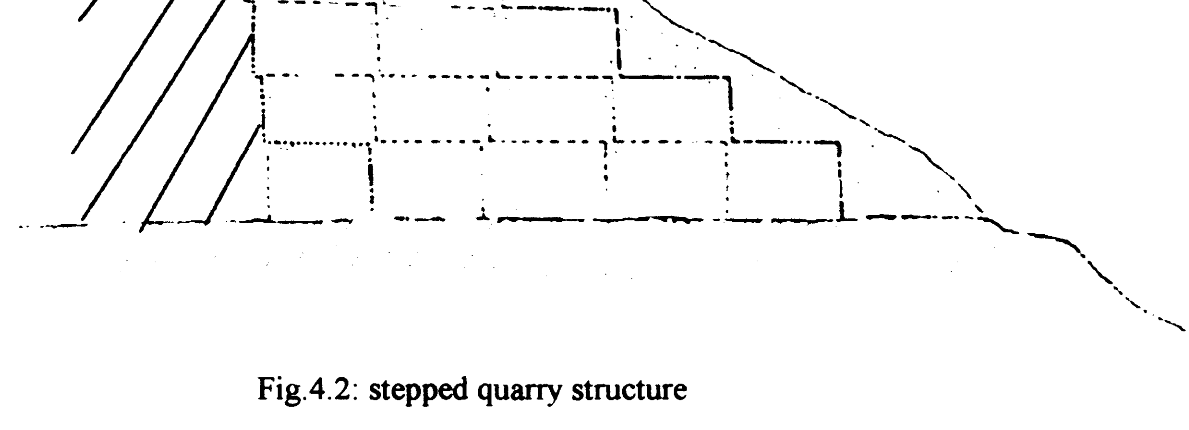


Fig.4.2: stepped quarry structure

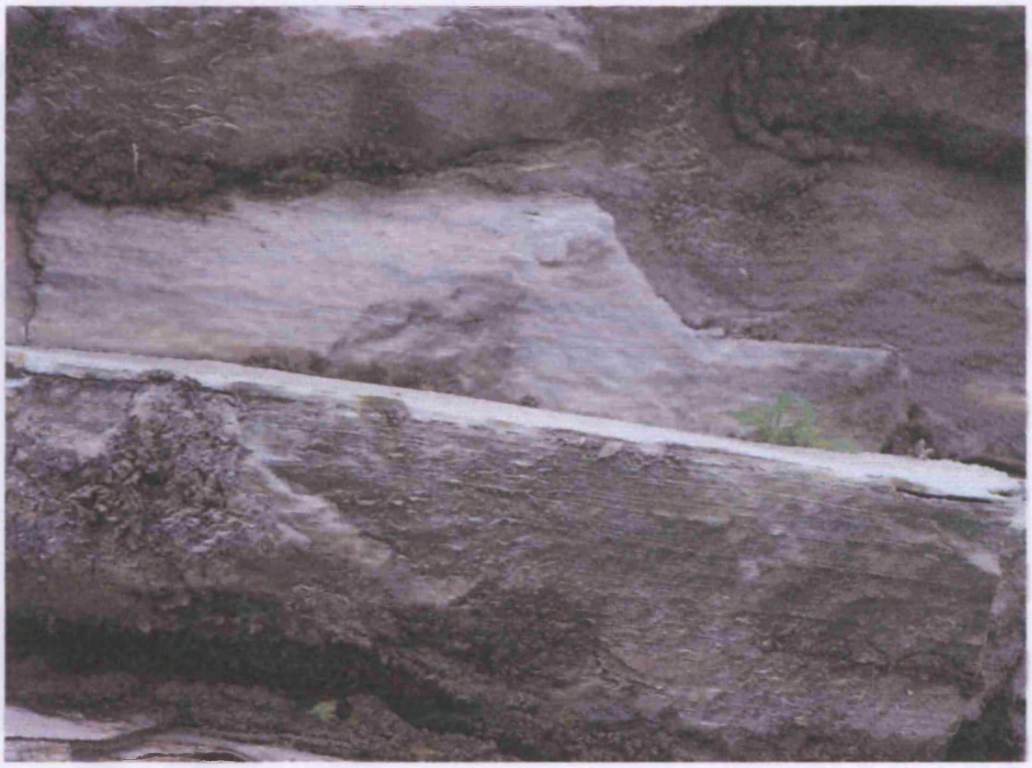


Fig.4.3: naturally split balatino at the outcrop of Plouti, Mesara

Fig.4.4: naturally split blocks of selenite at the outcrop of Myrtos along the modern road

Fig.4.5: two possibly quarried terraces at location LC2

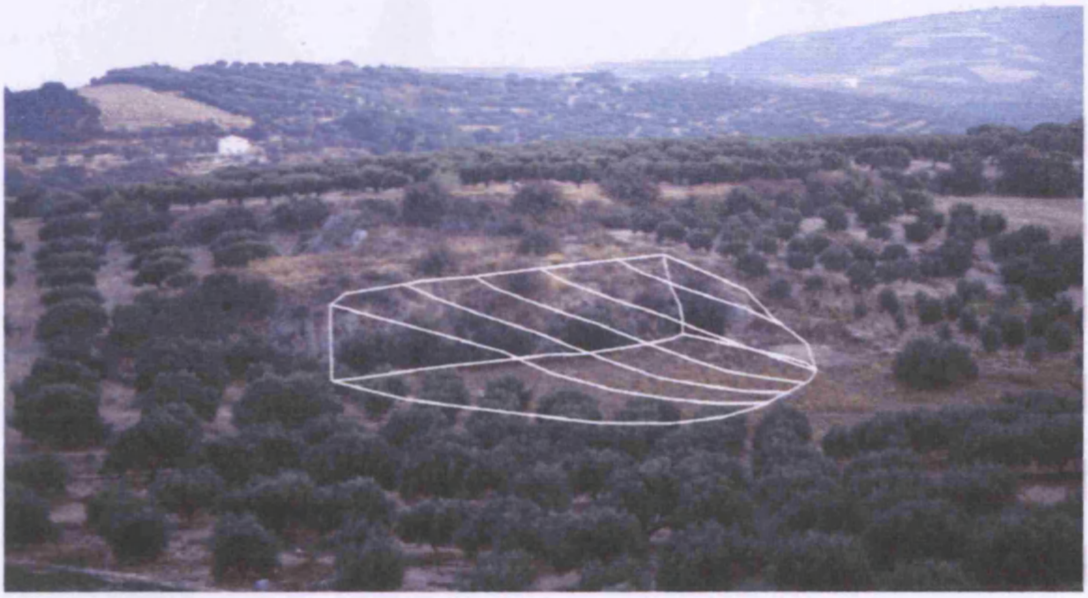


Fig.4.6: hypothetical bulk of gypsum removed from one of the terraces of location LC2, estimated bulk: 1000m²

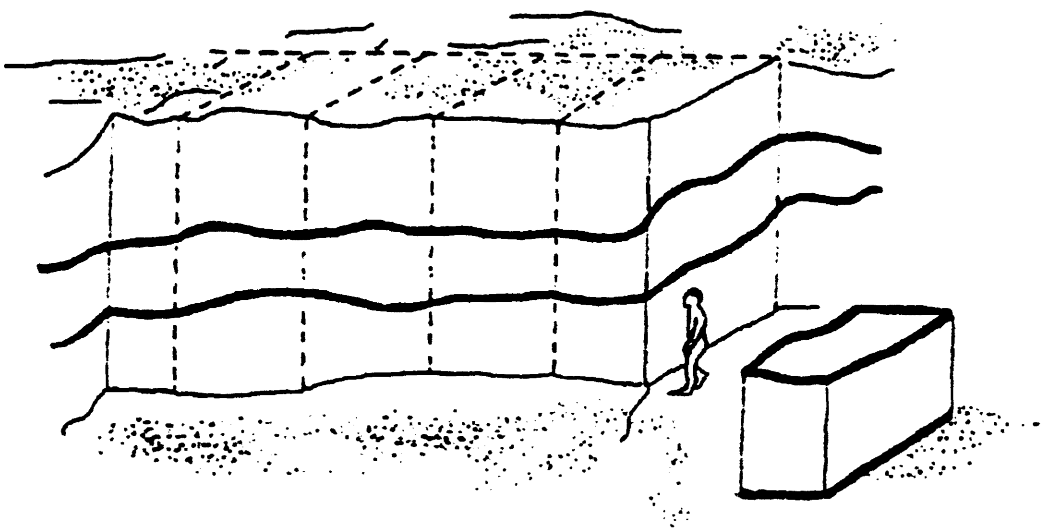


Fig.4.7: quarry of bedded stone, after Rockwell (1993:158, drawing 49)

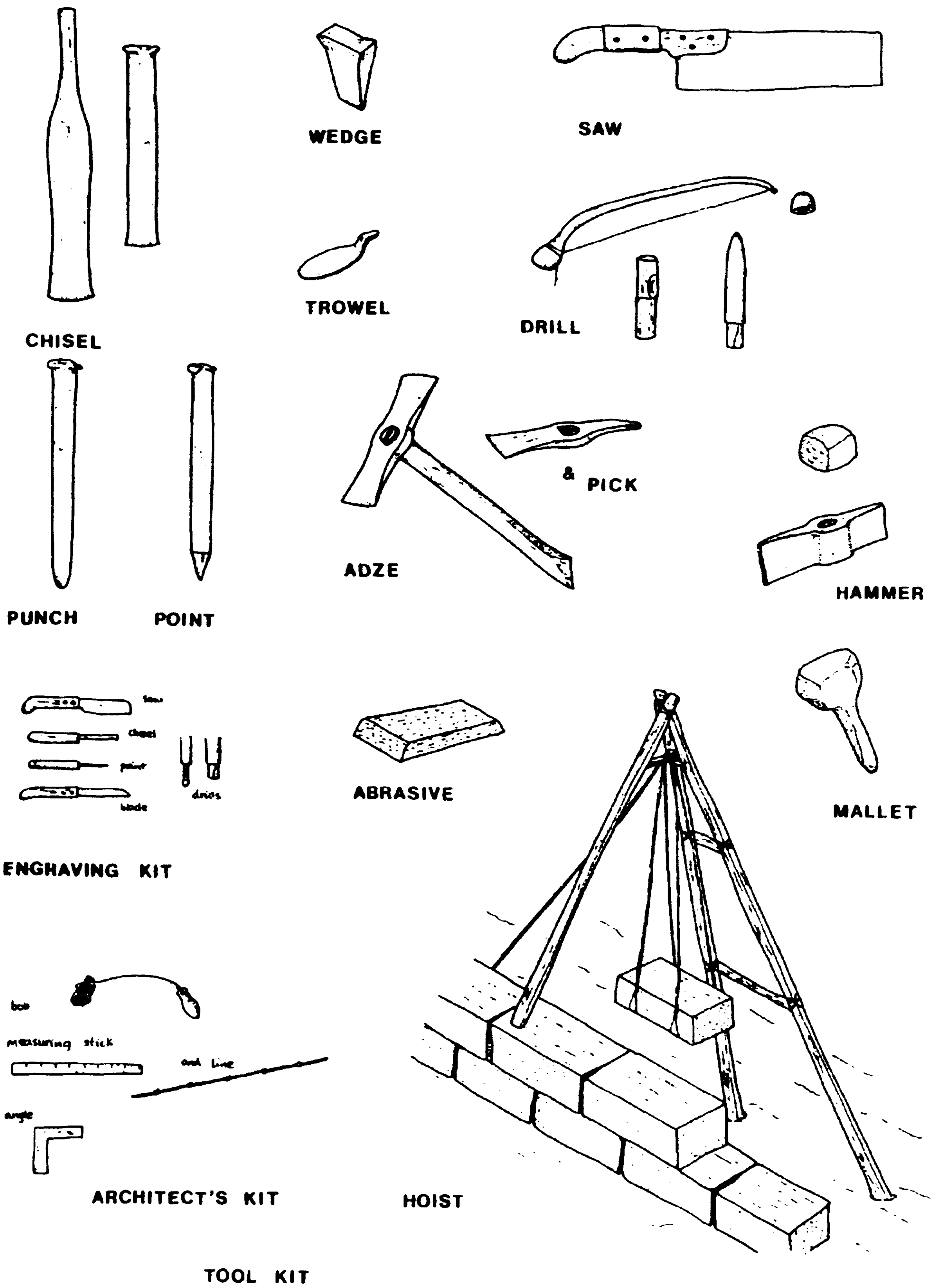


Fig.4.8: the architect's tool kit after Evely (1993:111,fig.84)

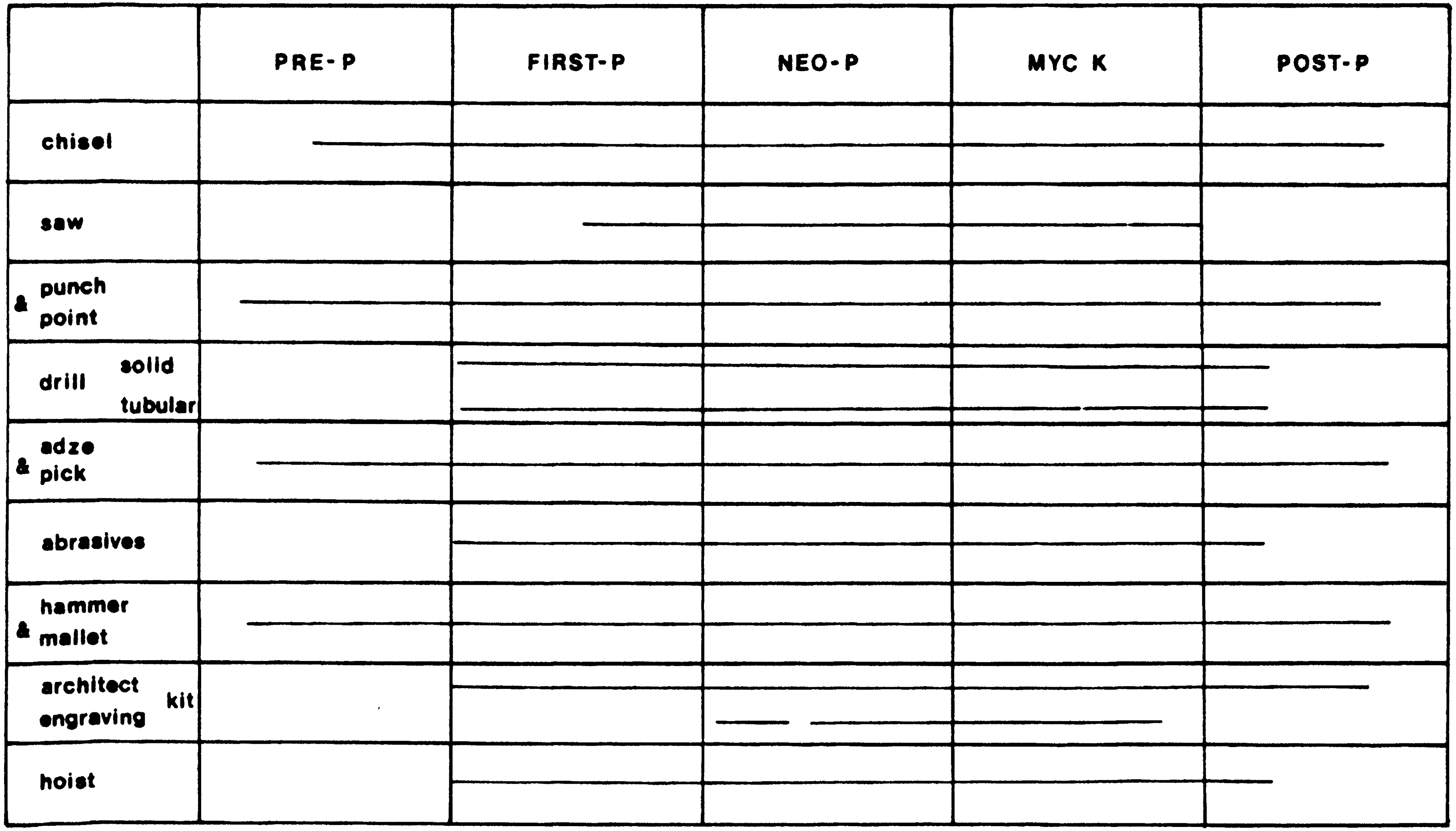


Fig.4.9:chronology of the most common architects and masons tools after Evely (1993:217, fig.88)

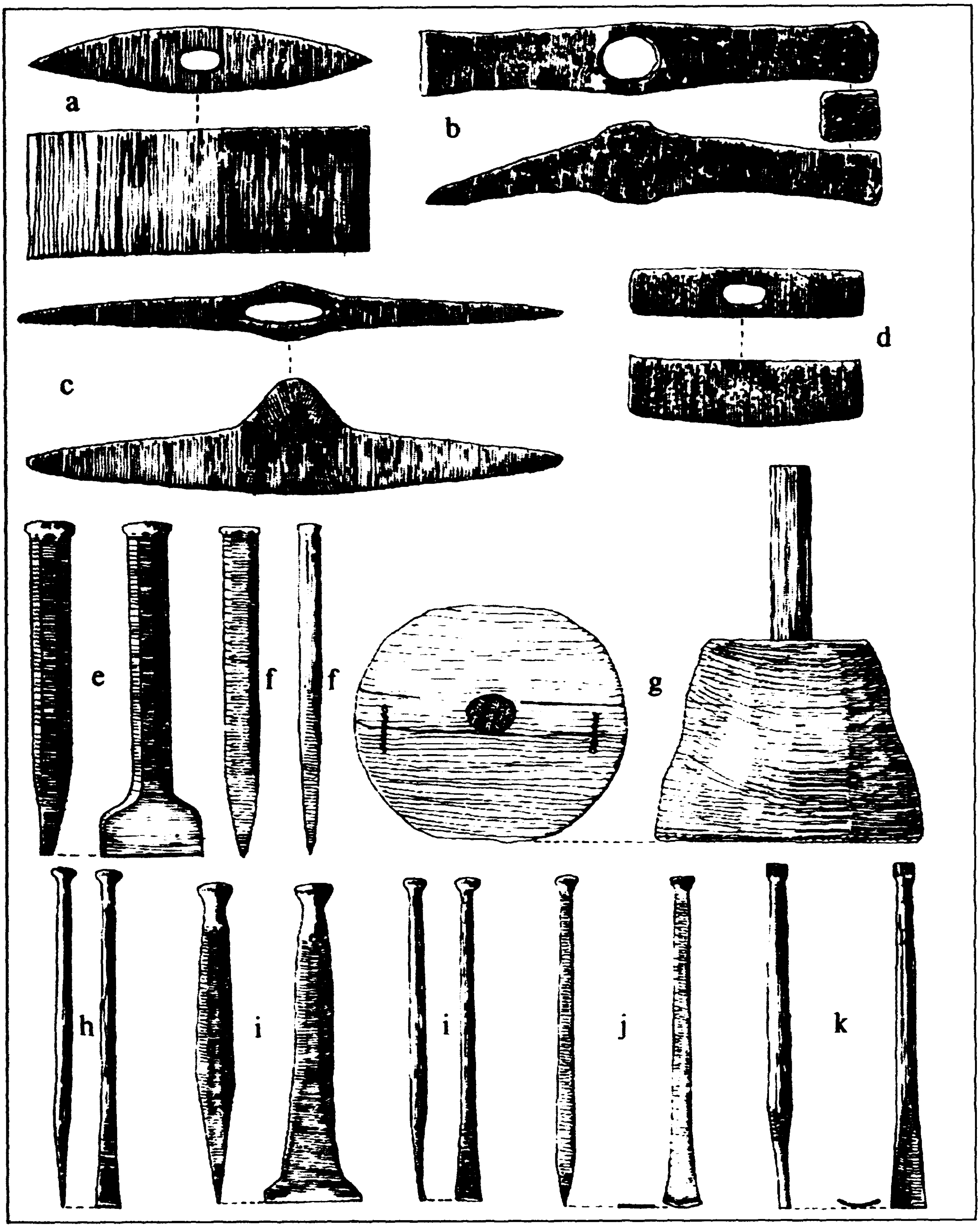


Fig.4.10: traditional tools of stone-working, after Hill (1990:101, Fig. 5.2): axe/adze (a, b), pick (c), hammer (d), pitcher (e), punch (f), mallet (g), claw tool (h), flat chisel (i), bull-nose chisel (j), gouge (k).

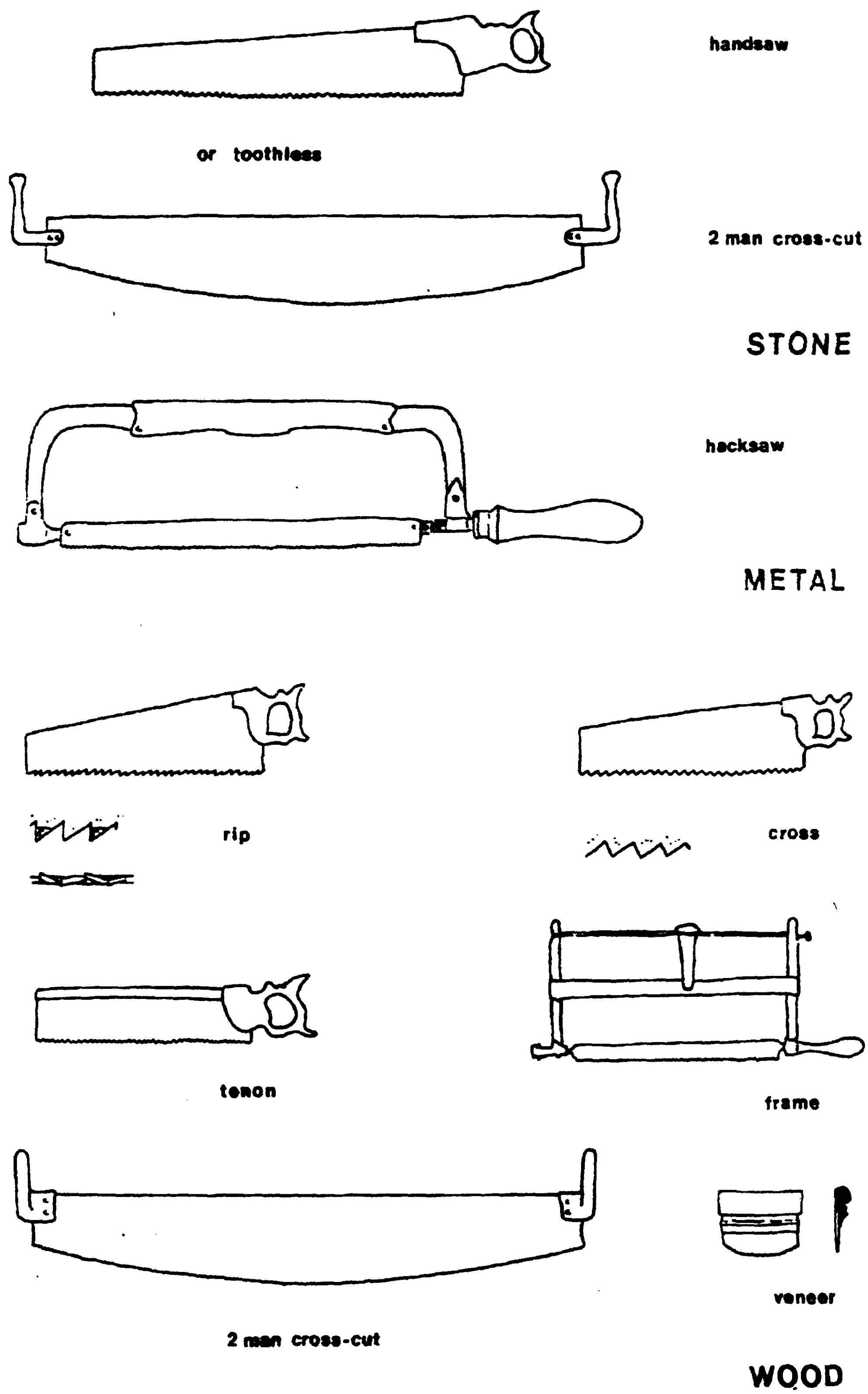
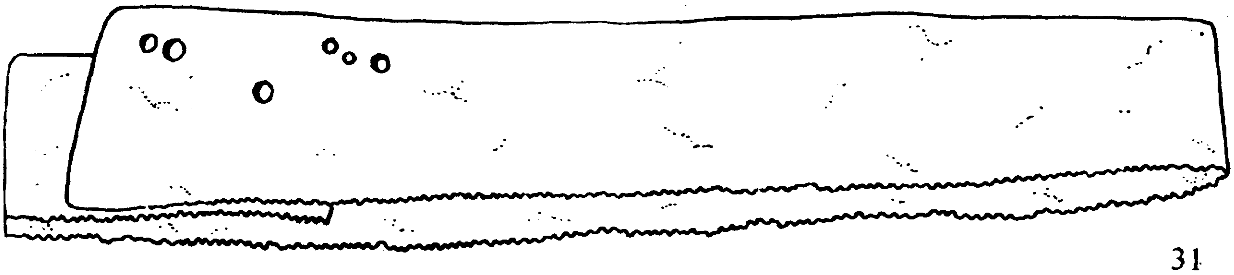


Fig.4.11: modern saw types after Evely (1993:27, fig 11)



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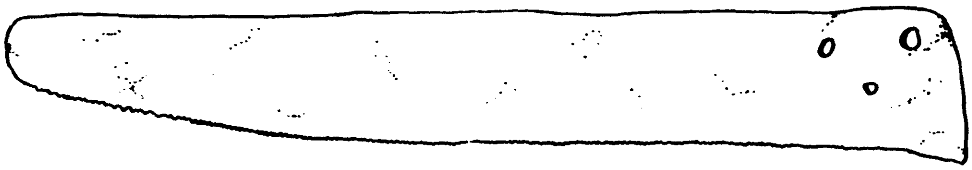

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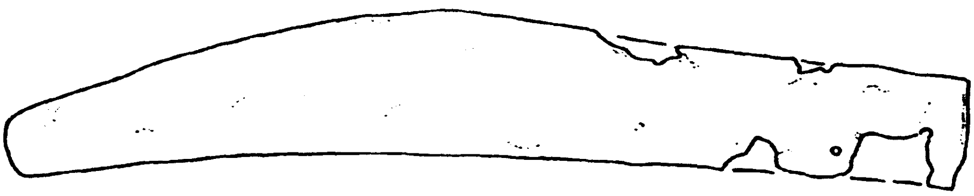

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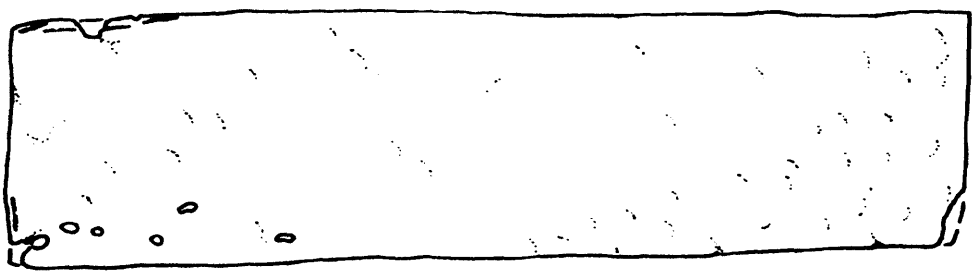


49

Fig.4.12: toothed sows from Zakros (31) Gournia (34) and Knossos (38) and toothless saws from Agia Triada (46,49), after Evely (1993:30,32 fig.13,14)

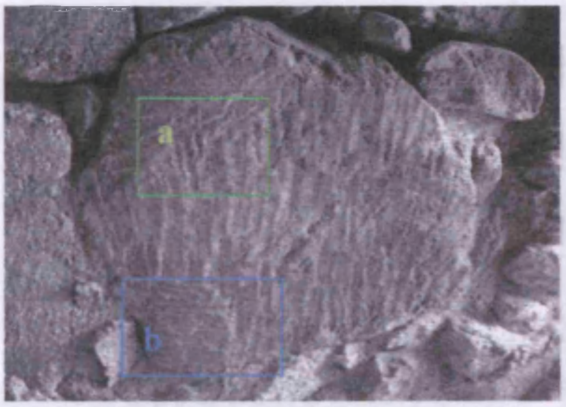


Fig.4.13: chisel and possible axe/adze marks on a selenite block at the 'Basement Passage Under the Corridor of the Cup Bearer'

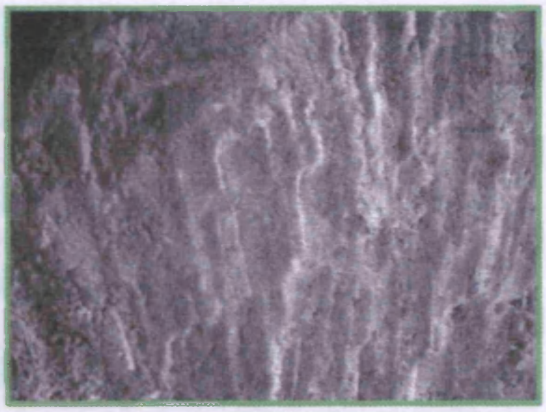


Fig.4.14: detail (a) from photo 4.13

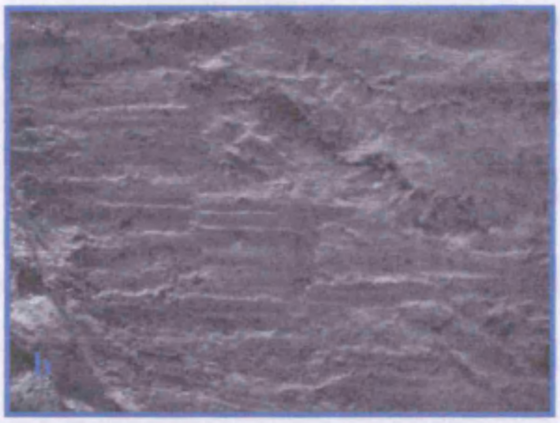


Fig.4.15: detail (b) of Fig.4.13, horizontal overlapping marks of chisel in successive rows

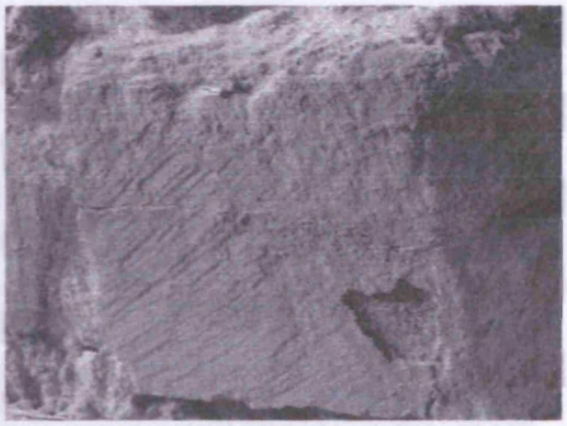


Fig.4.16: fine chisel marks on a selenite block at the Basement Passage under the Corridor of the Cup Bearer

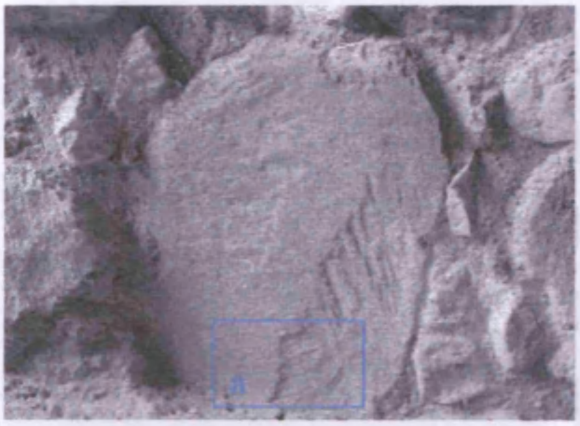


Fig.4.17: mark of at least two different tools on a selenite block at the Basement Passage under the Corridor of the Cup Bearer

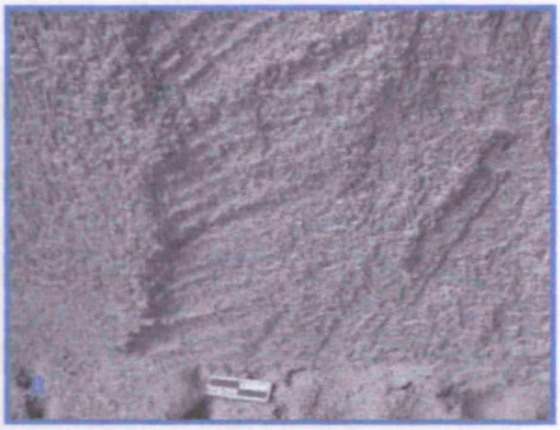


Fig. 4.18:detail (a) of Fig.4.17

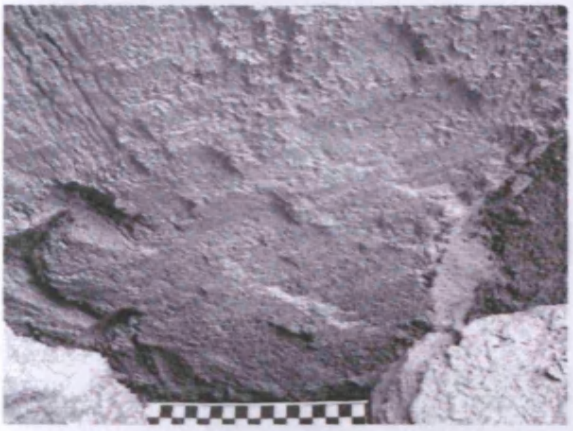


Fig.4.19: parallel overlapping chisel marks on selenite block built into the south wall of Magazine I

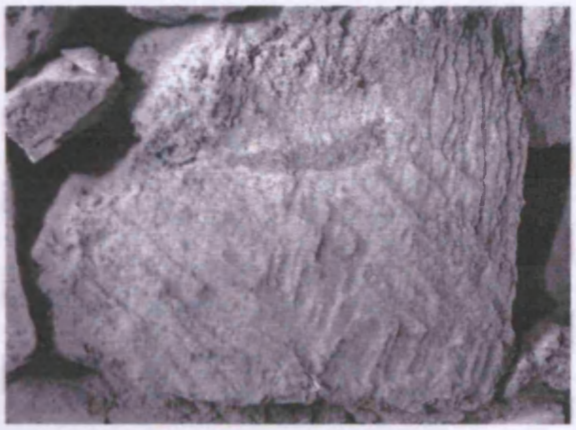


Fig.4.20: crossing chisel marks on reused block in the 'Early Passage Way with Proto-palatial Magazines'

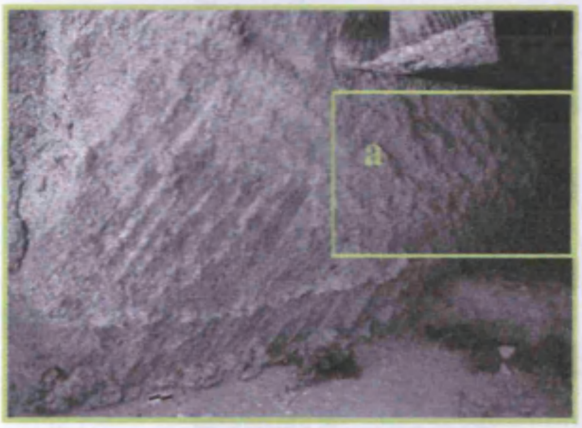


Fig.4.21: overlapping tool marks, probably of flat chisel, on the surface of selenite block on south wall of Magazine VIII, cut in two crossing directions

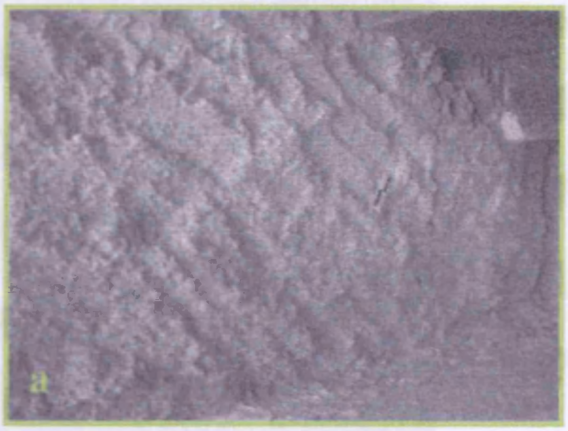


Fig.4.22: detail (a) of previous photo

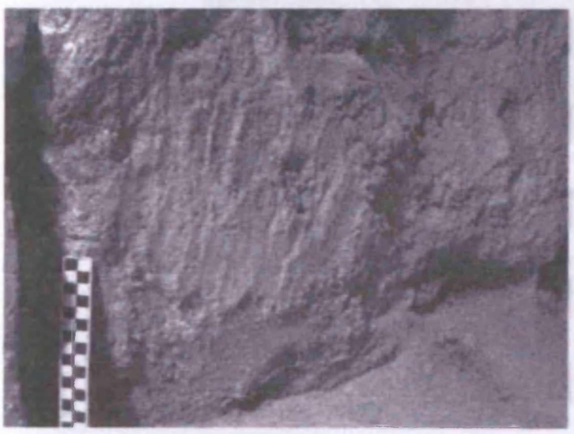


Fig.4.23: axe/adze marks in Magazine XII

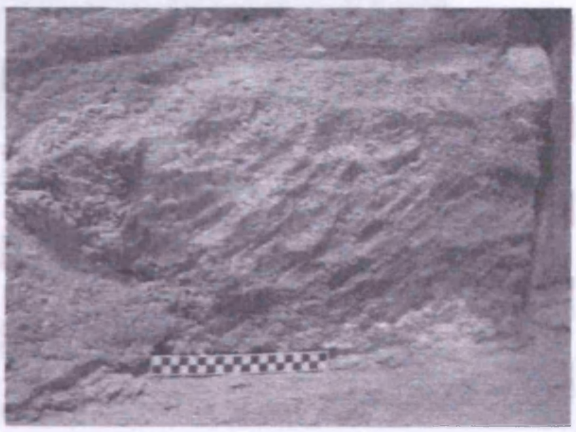


Fig.4.24: punch or blunted pick marks in Magazine X

Fig.4.25:chisel marks on the upper block and characteristic pick marks with a V-shaped groove on the lower block, found in the second niche at the South Terrace Basements

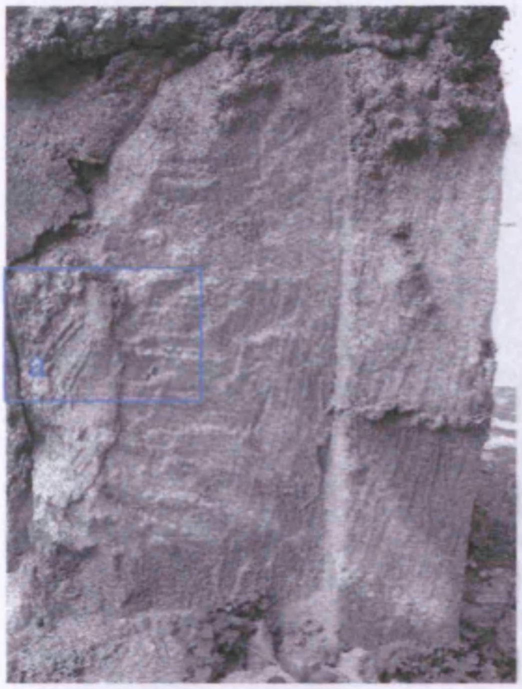


Fig.4.26: chisel marks on the rear side of lower block of the north jamb in Magazine III

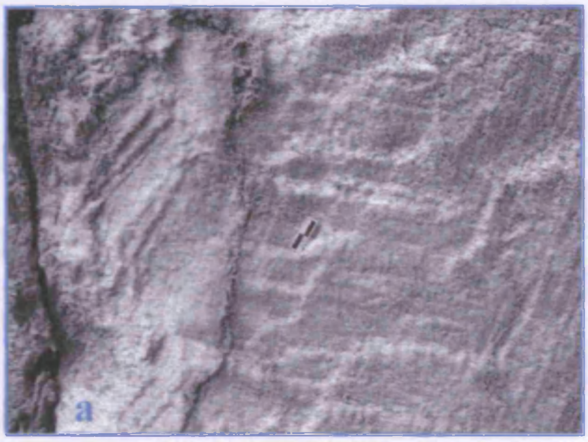


Fig.4.27: detail (a) of chisel marks on the lower block of the north jamb in Magazine III

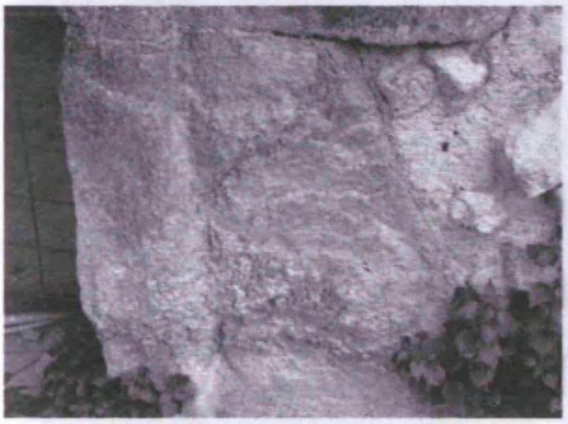


Fig.4.28: chisel marks on the lower block of the south jamb in Magazine III

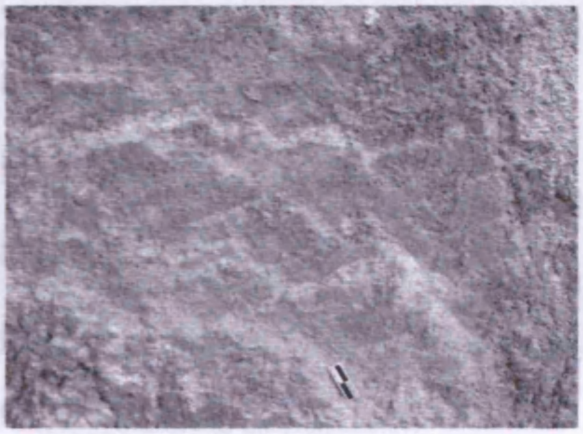


Fig. 4.29: chisel marks on the lower block of the north jamb in Magazine III

Fig. 4.30: tool marks, probably of axe/adze on the rear side of the south jamb of Magazine VIII

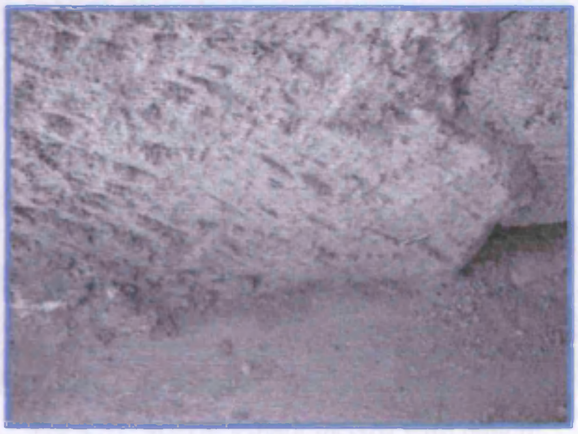


Fig. 4.31: detail (a) of previous photo

Fig.4.32: mason's mark incised with punch mark, (Early Passage Way with Protopalatial Magazines)

Fig.4.33: mason's mark incised with punch mark on surface worked with chisel (Early Passage Way with Protopalatial Magazines)

Fig.4.34: mason's mark incised with punch mark on surface worked with chisel (Long Gallery of the Magazines)

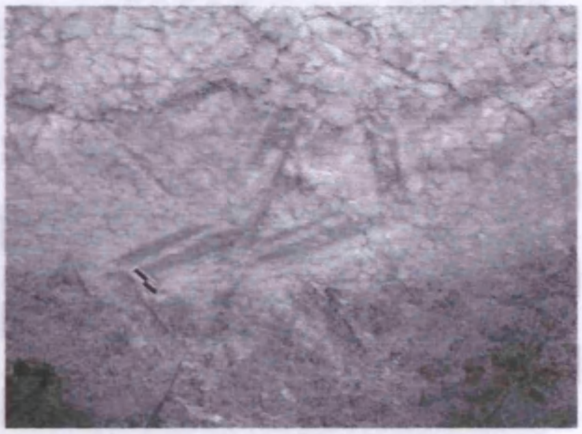


Fig.4.35: mason's mark incised with chisel (Long Gallery of the Magazines)

Fig.4.36: mason's mark incised with punch (Long Gallery of the Magazines)

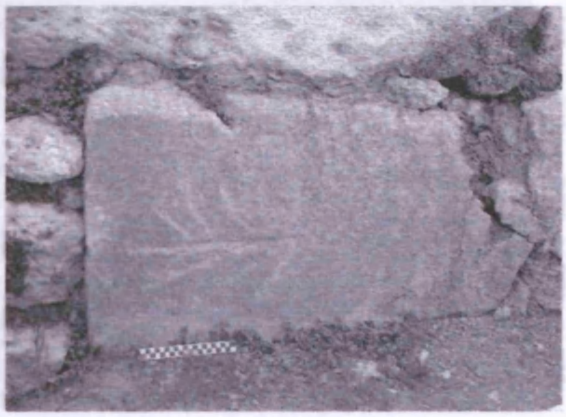


Fig.4.37: mason's mark incised with punch (north- south axe of Corridor of the Stone Basin)

Fig.4.38: tool marks on loose slabs at the Pyrgos country house : a) hand saw, b) flat chisel 2cm wide, c, d, and e) flat chisel

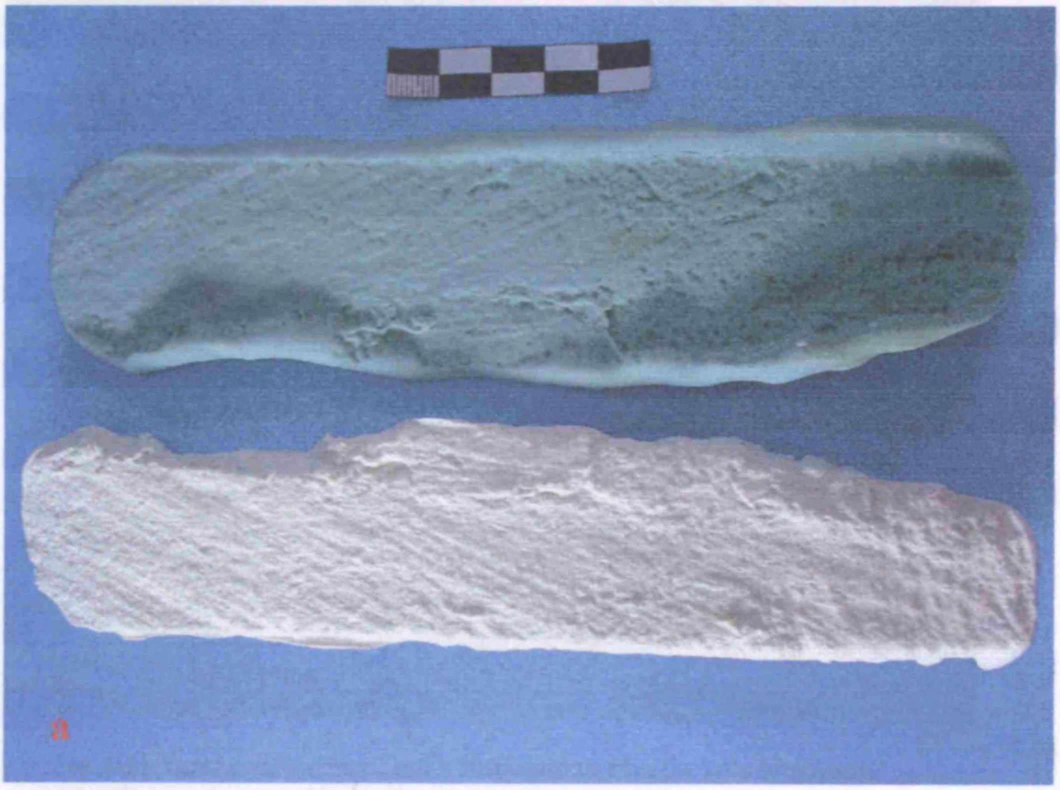


Fig.4.39: cast of saw marks from Pyrgos

Fig.4.40: combined work of saw and chisel on the side of loose slab from Pyrgos

Fig.4.41: hand saw used by Levi's workman to trim the side of gypsum slab (photo courtesy of the Italian School of Archaeology, also published by Shaw (1973:68, Fig.60b)

Fig.4.42: flat chisel marks 2cm wide on back surface of loose slab from Pyrgos

Fig.4.43: flat chisel marks on the side of loose slab from Pyrgos

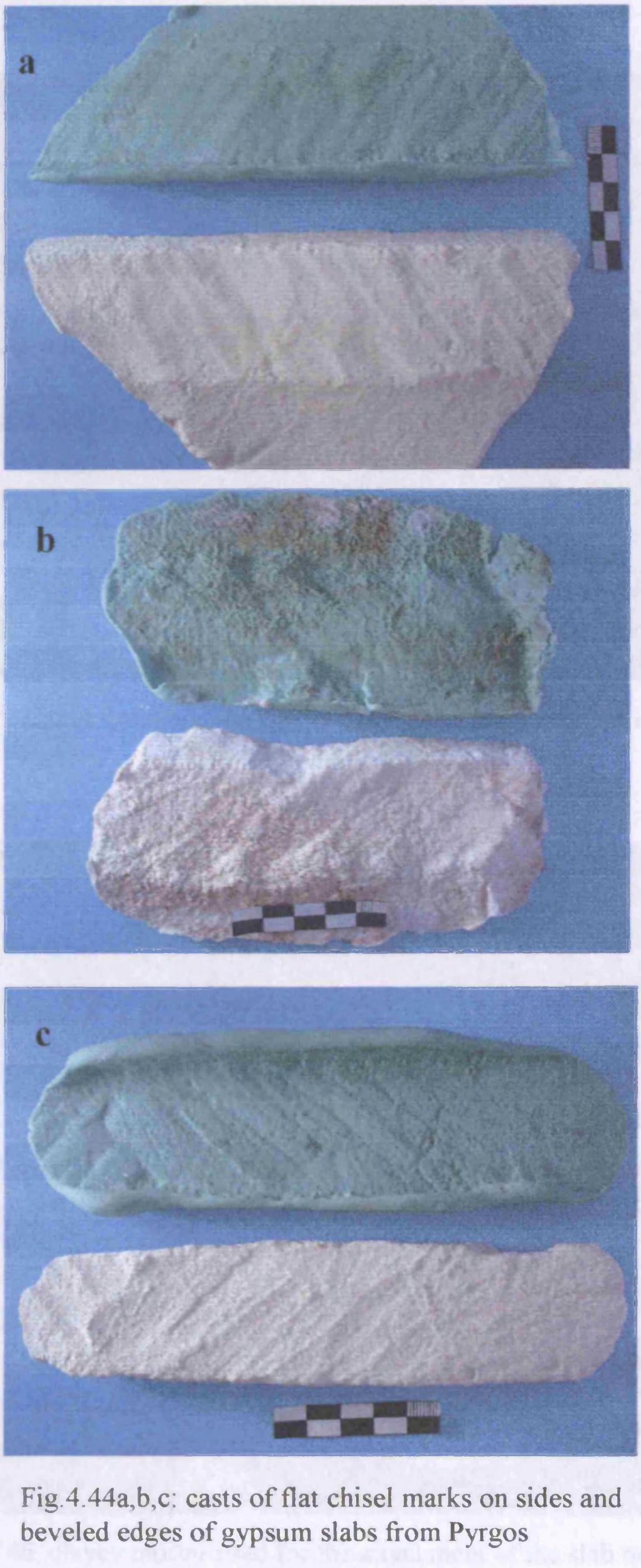


Fig.4.44a,b,c: casts of flat chisel marks on sides and beveled edges of gypsum slabs from Pyrgos

Fig.4.45: flat chisel marks on the rear sides of the a gypsum doorjamb base at Magaron Nirou

Fig.4.46: clayey mortar used for the attachment of the slab on to the walls, west wall of Room 45 in Agiia Triada

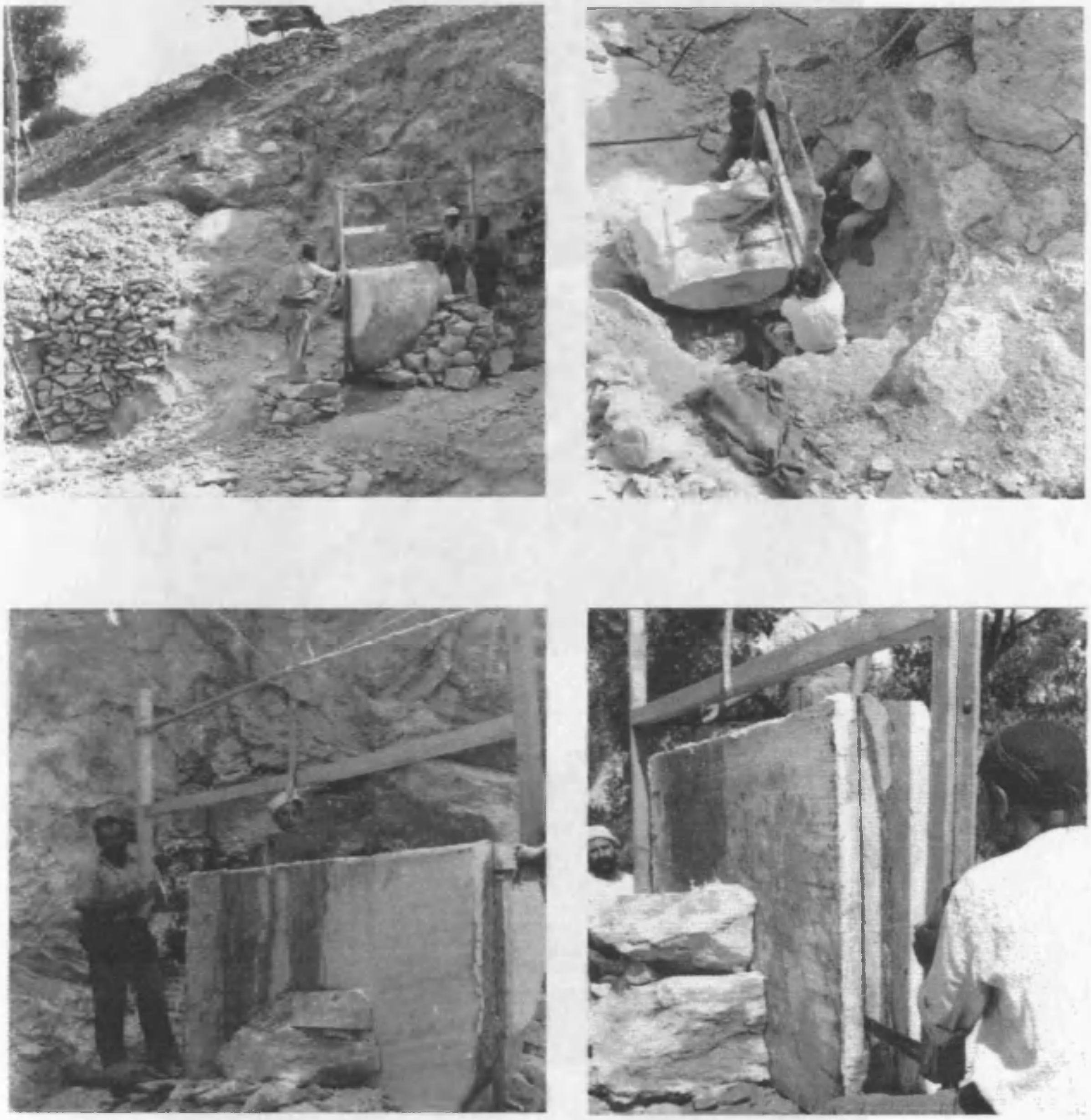


Fig 4.47a-d: use of steel toothless mason's saw in the Phaistos restoration campaign of Levi in the 1950's

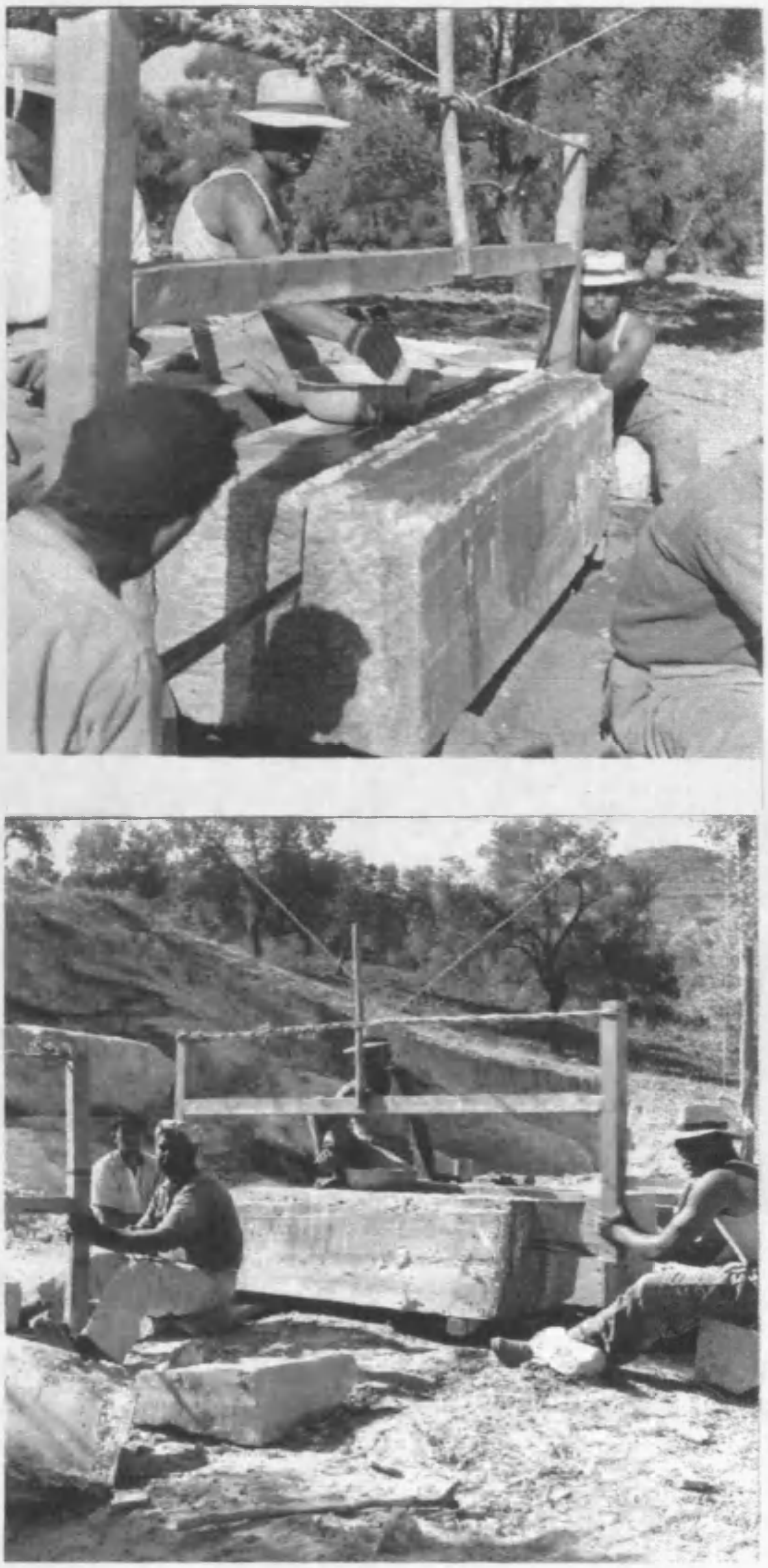
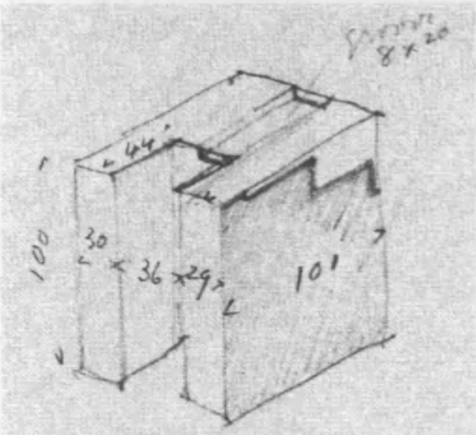


Fig.4.48a,b: sawing stone with the help of water as a cooling agent and abrasive powder



Approximate weight of the block: 2Kg or two tons

Fig.4.49: C. Doll supervising the re-positioning of the landing block of the fourth flight of the Grand staircase at Knossos (photo published by A.Brown 1994:98, fig.52a and 52b)

Fig.5.1: distribution of gypsum on a schematic plan of the palace of Knossos

Fig. 5.2: the great gypsum orthostates of the West Façade at the palace of Knossos.

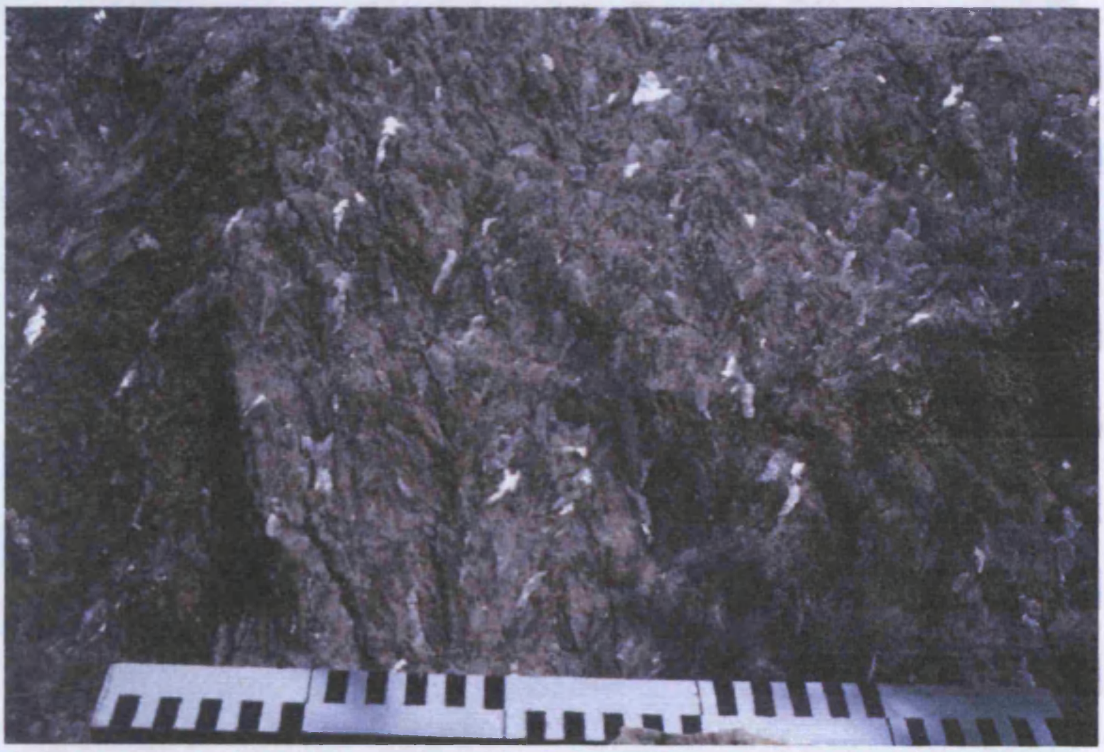


Fig. 5.3: selenite surface from a fresh face of the stone in the outcrops of the Gypsades Hill.

Fig. 5.4: transition line of burned/unburned selenite orthostate of the West Façade at the Palace of Knossos

Fig. 5.5: selenite orthostate unaffected by fire, at the north end of the façade

Fig. 5.6: unaffected selenite blocks under and in front of the *krepidoma* of the West Facade

Fig. 5.7: Fire marks on the selenite blocks north of the krepidoma of the West Facade

Fig. 5.8: column base of West Porch *KN* 4

Fig. 5.9: unaffected part of column base *KN*4

Fig. 5.10: restored gypsum walkways and selenite orthostates of the west wall of the West Porch at the Palace of Knossos

Fig. 5.11: the gypsum walkways of the West Porch and the Corridor of the Procession

Fig. 5.12: the wooden frame of the door is clearly marked by the whitening of the selenite on the partly burned doorjamb base (KN 6) at the entrance of the West Porch

Fig. 5.13: alteration of the outer surface of selenite ashlar block (KN 40) due to fire

Fig. 5.14: threshold slabs of banded selenite at the West Porch entrance to the Corridor of the Procession Fresco

Fig. 5.15: original (left *KN*36) and modern (right *KN*38) gypsum slabs at the beginning of the Corridor of the Procession Fresco

Fig. 5.16: abandoned blocks most probably from the collapsed south-west corner of the building

Fig. 5.17: gypsum blocks in secondary use, built in the south wall of the South Terrace Basements (notice mortises and double axe mason's mark)

Fig. 5.18: gypsum blocks in secondary use on the other side of the wall shown above (notice double axe mason's mark on the right)

Fig. 5.19: north doorway of the South West Columnar Chamber (viewed from south)

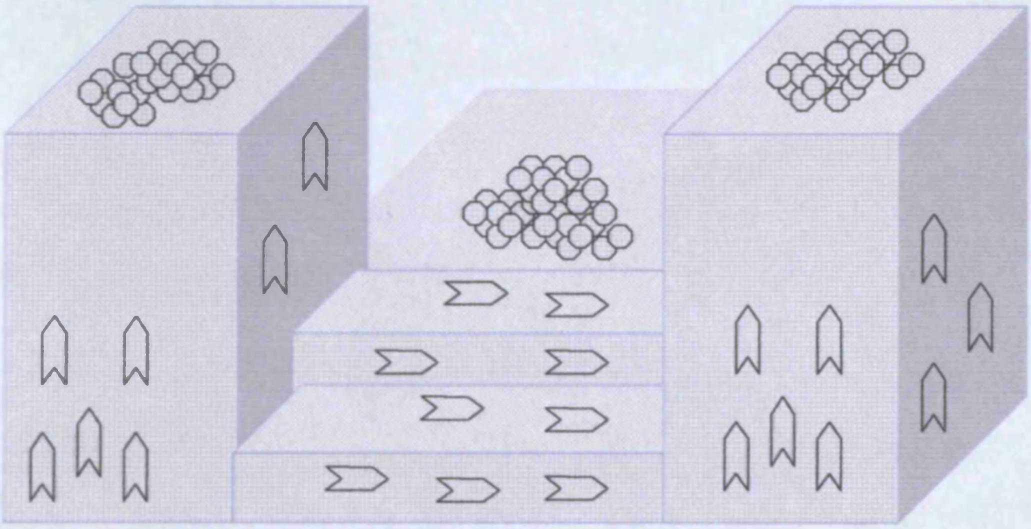


Fig. 5.20: crystal orientation on the selenite blocks of the doorway that is shown above

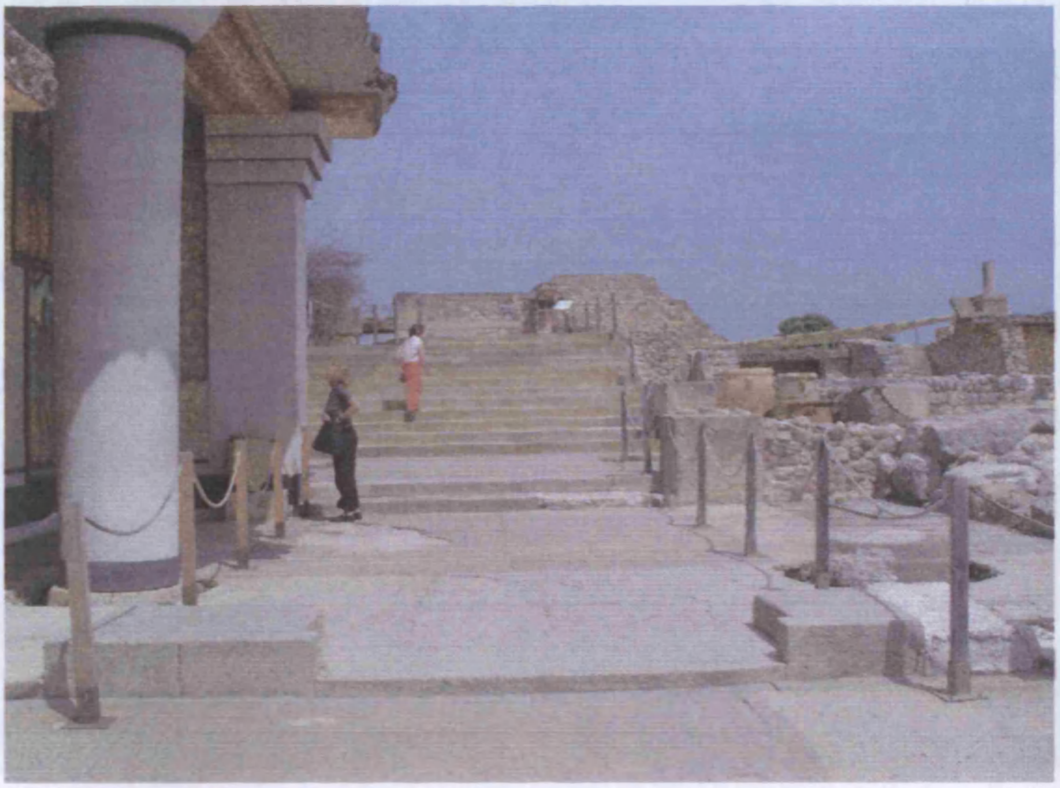


Fig. 5.21: South Propylaeum, general view from south

Fig. 5.22: selenite doorjamb base at the entrance of Magazine A (*KN*210)

Fig. 5.23: selenite blocks in the wall between Magazines A and B (KN211-217)

Fig. 5.24: selenite blocks built into the east wall of Magazine A

Fig. 5.25: nodular and lenticular gypsum block with parallel laminations in Magazine A (KN1718)

Fig. 5.26: reused block with mason's mark in north wall of Magazine A

Fig. 5.27: *cross paté* mason's mark on south wall of the Corridor of the Stone Jambs

Fig. 5.28: selenite blocks with *cross paté* mason's marks partly affected by fire

Fig. 5.29: the south jambs of Magazine I (note mason's marks)

Fig. 5.30: unaffected selenite blocks and orthostates built into the south and west wall of Magazine I, transition line of affected/unaffected by fire

Fig. 5.31: selenite blocks and orthostates built into the north and the west wall of Magazine I, transition line of affected/unaffected by fire

Fig. 5.32: *cross paté* mason's mark and tool marks on a selenite block built into the south wall of Magazine I

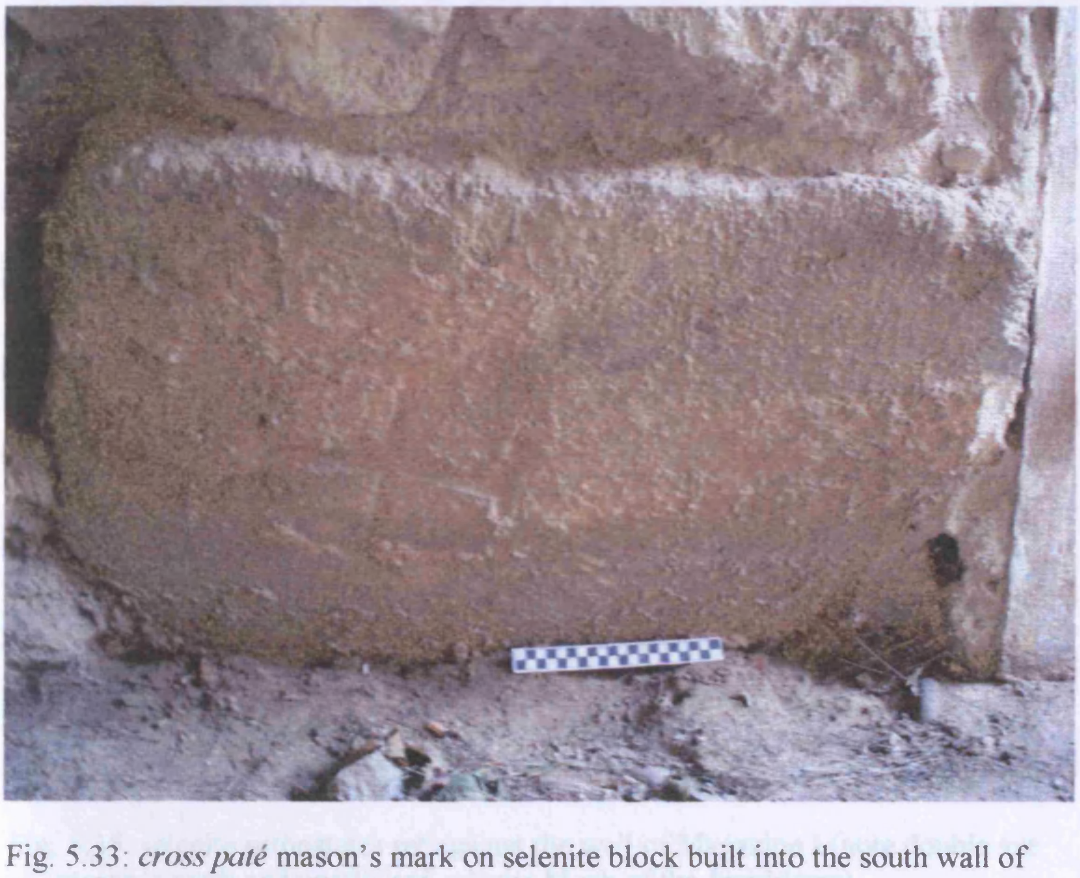


Fig. 5.33: *cross paté* mason's mark on selenite block built into the south wall of Magazine I

Fig. 5.34: window mason's mark on selenite block built into the north wall of Magazine I near the entrance (east end of wall)

Fig. 5.35: selenite orthostates set against the wall of Magazine I (note double axe mason's mark and unaffected selenite block of the *krepidoma*)

Fig. 5.36: the south jamb of Magazine II (note mason's marks)

Fig. 5.37: transition line on selenite blocks of the south and the north wall of Magazine II, also note partly preserved '*cross paté*' mark

Fig. 5.38: the orthostates set against the west wall of Magazine II (note double axe mason's marks

Fig. 5.39: the south jambs of Magazine III

Fig. 5.40: general vie of Magazine III

Fig. 5.41: deeply curved double axe mason's mark on north wall of Magazine III

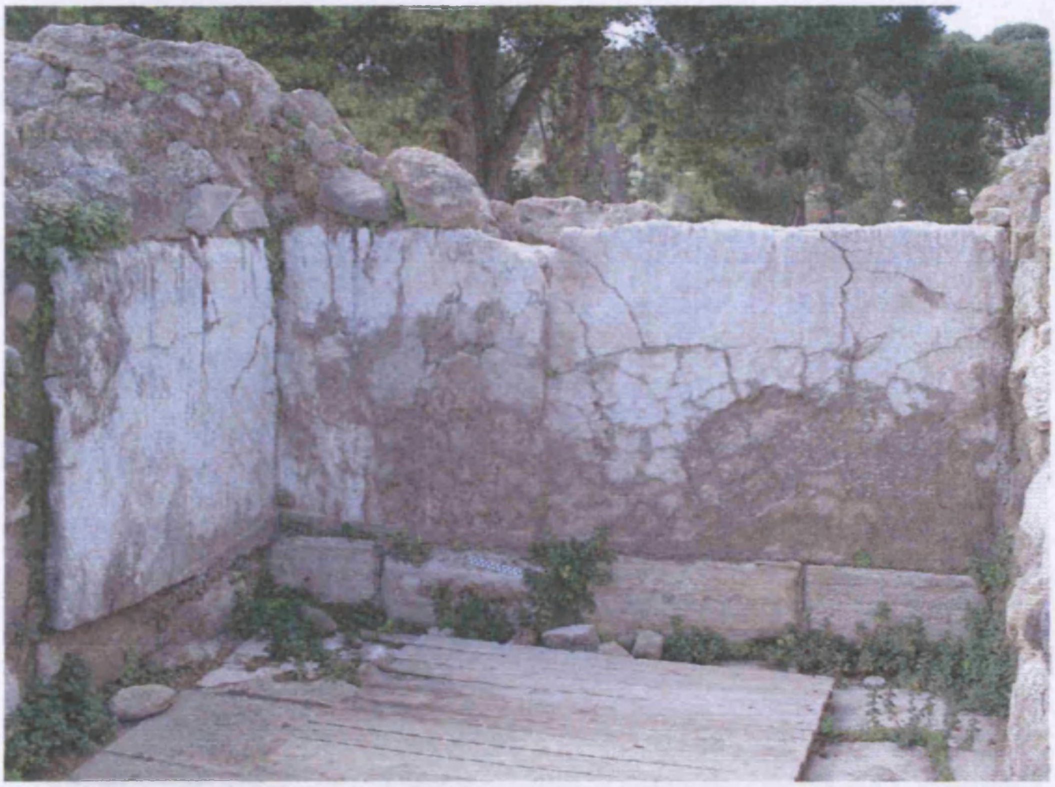


Fig. 5.42: orthostates of the south and west walls in Magazine III

Fig. 5.43: limestone and gypsum floor slab remains in Magazine III

Fig. 5.44: the north orthostate of Magazine IV, exposed to outdoors environment

Fig. 5.45: general view of Magazine IV

Fig. 5.46: the orthostates of the west wall of Magazine IV

Fig. 5.47: black staining of the floor slabs and the walls in magazine IV

Fig. 5.48: cist lining, note difference between preservation of upper (affected by fire) and lower (unaffected by fire) parts

Fig. 5.49: the south orthostate of Magazine V

Fig. 5.50: general view of Magazine V

Fig. 5.51: the cist in the south wall of Magazine V

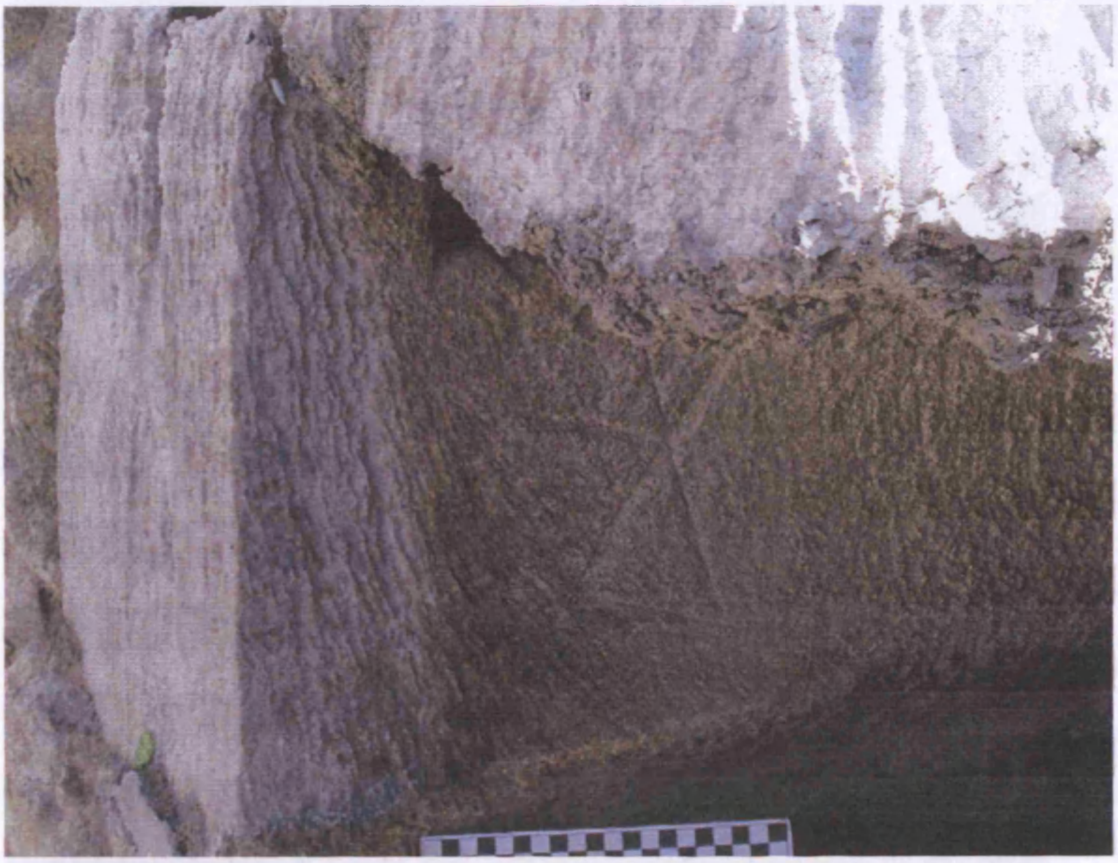


Fig. 5.52: upper, east side of the wall cist in Magazine V

Fig. 5.53: the orthostates of Magazine V

Fig. 5.54: the south jamb of Magazine VI

Fig. 5.55: general view of Magazine VI

Fig. 5.56: the orthostates of the west wall

Fig. 5.57: the lining of the seventh cist in Magazine VI

Fig. 5.58: the lining in the third cist in Magazine VI

Fig. 5.59: the south jamb of Magazine VII


Fig. 5.60: entrance, cists and gypsum paving of Magazine VII


Fig. 5.61: the orthostates of the west wall in Magazine VIII

Fig. 5.62: fire marks at the entrance of Magazine VII, note double axe mark on the left block

Fig 4.63: selenite pseudomorphs of the upper block of the north jamb in Magazine VII

Fig. 5.64: the south jamb of Magazine VIII

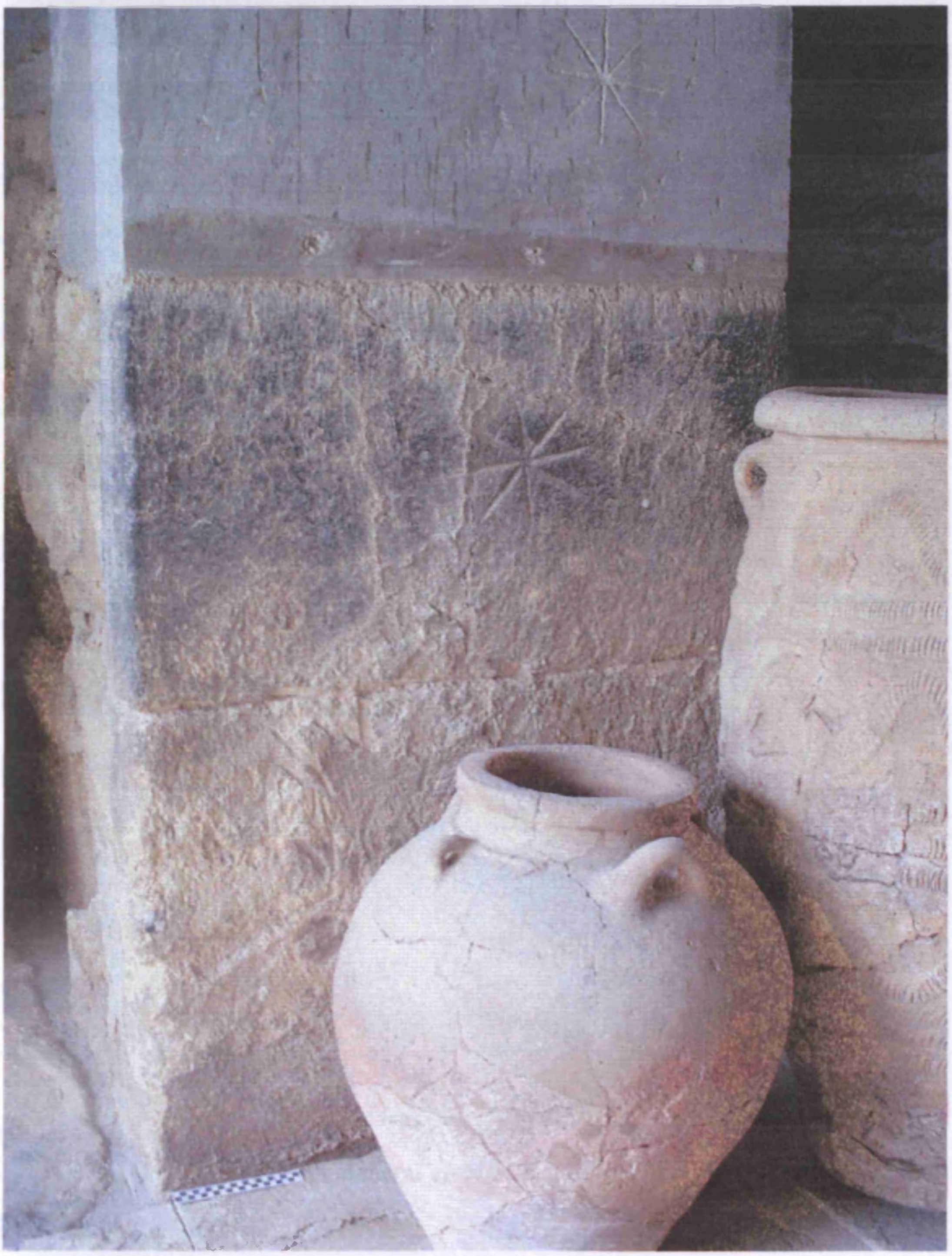


Fig. 5.65: the south jamb of Magazine IX

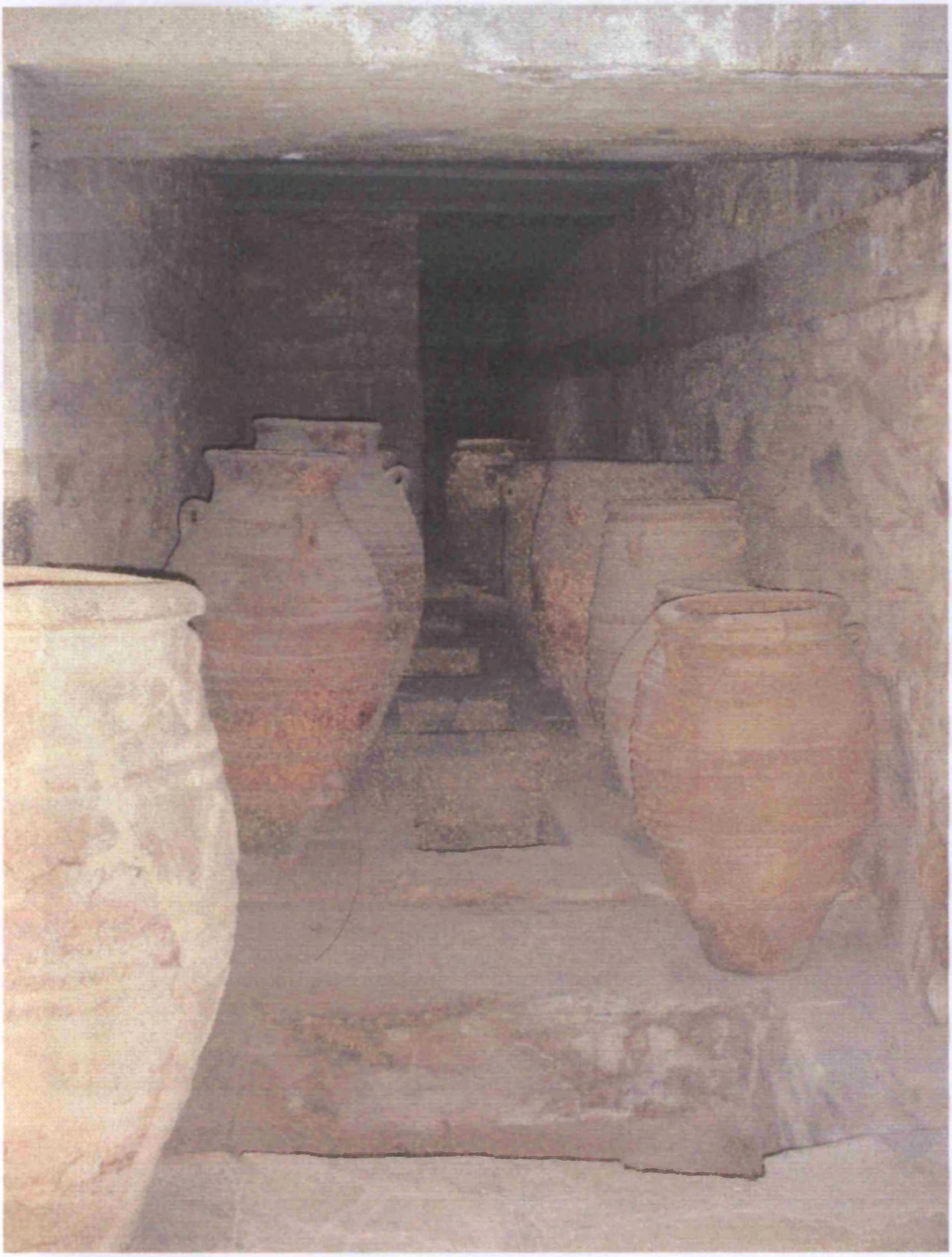


Fig. 5.66: general view of magazine IX

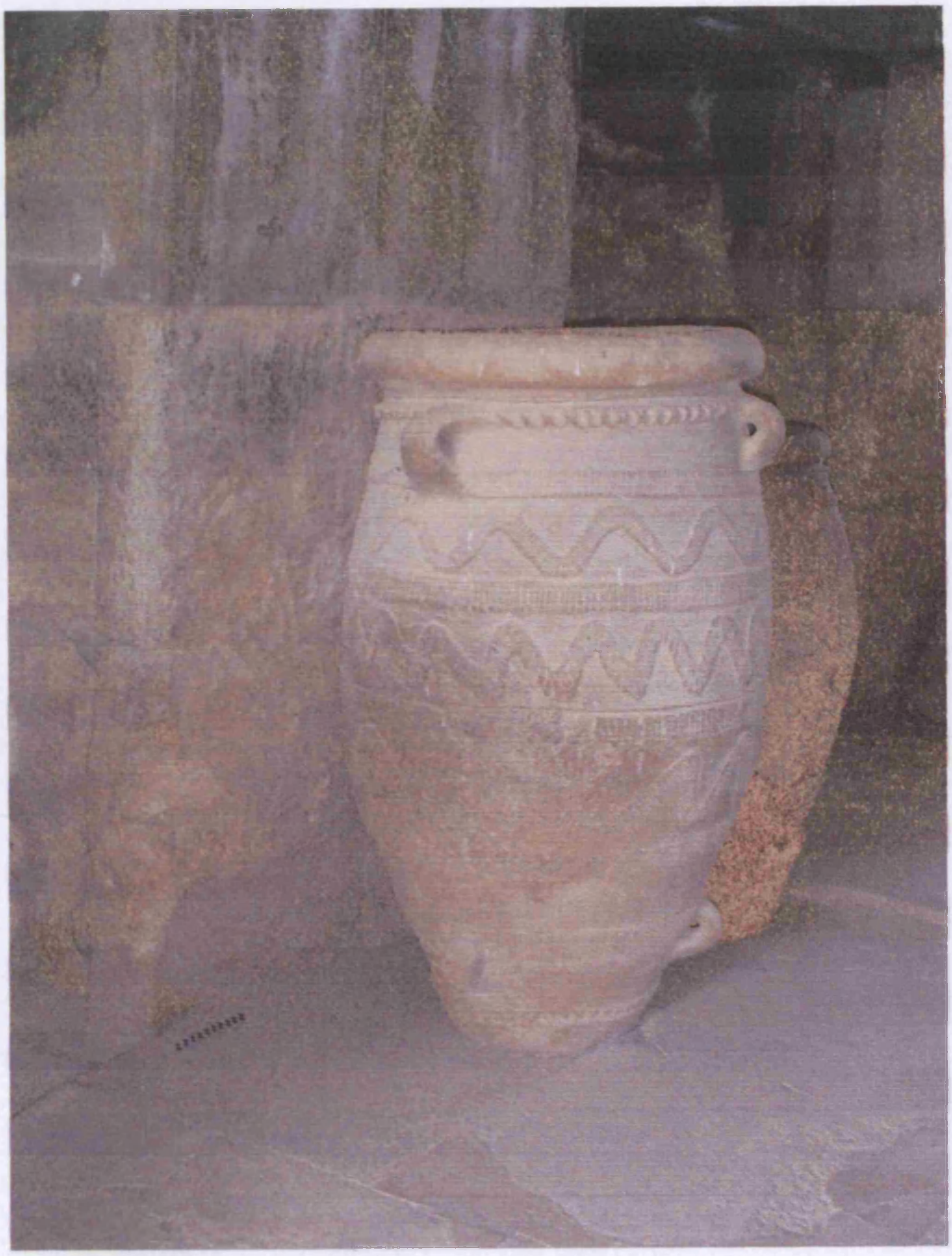


Fig. 5.67: the south jamb of Magazine X

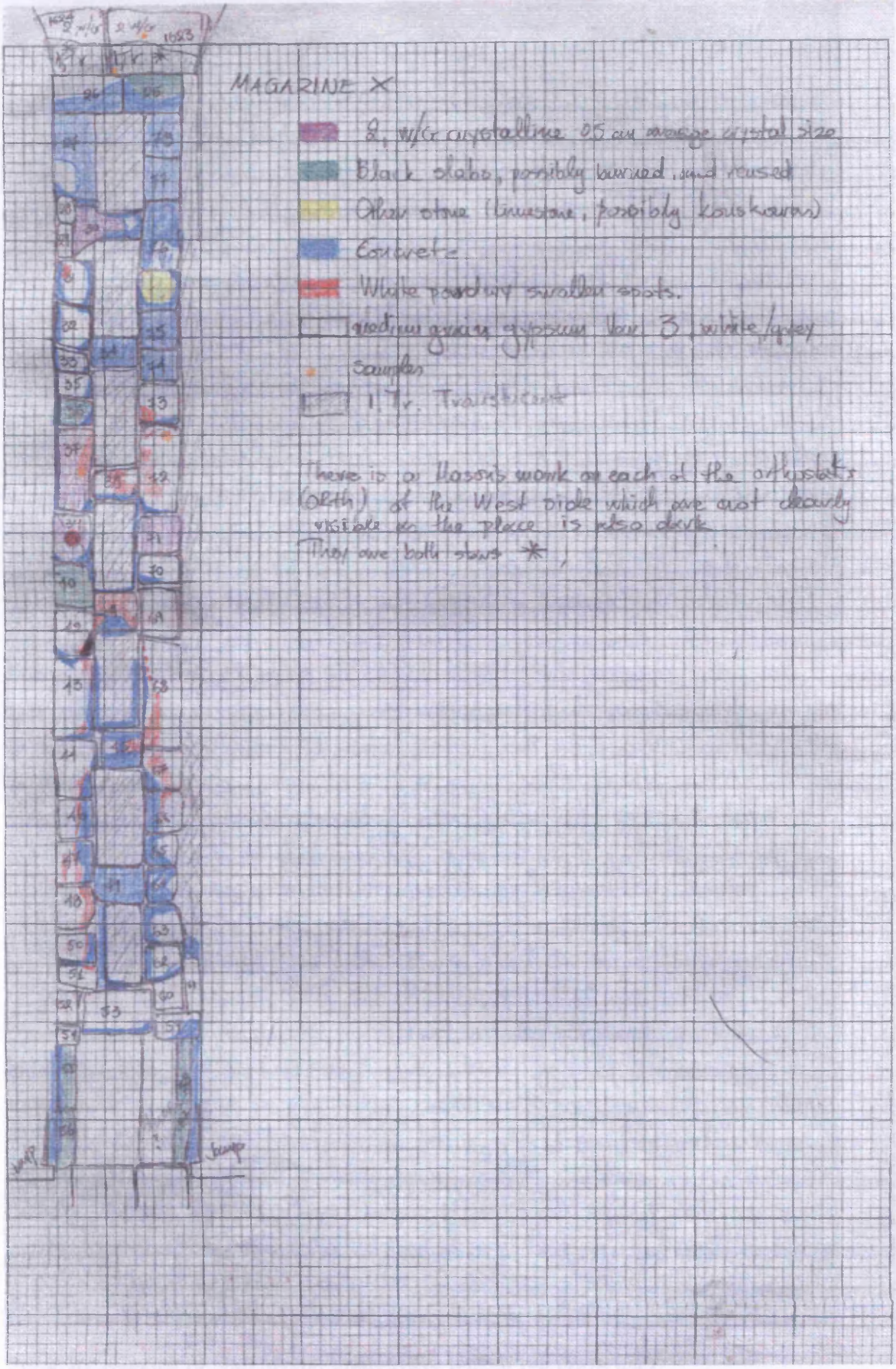


Fig. 5.68: draft map of gypsum varieties and weathering forms in Magazine X

Fig. 5.69: the orthostates of the west wall in Magazine X

Fig.4.70: remains of wall plaster at the lower part of the north wall

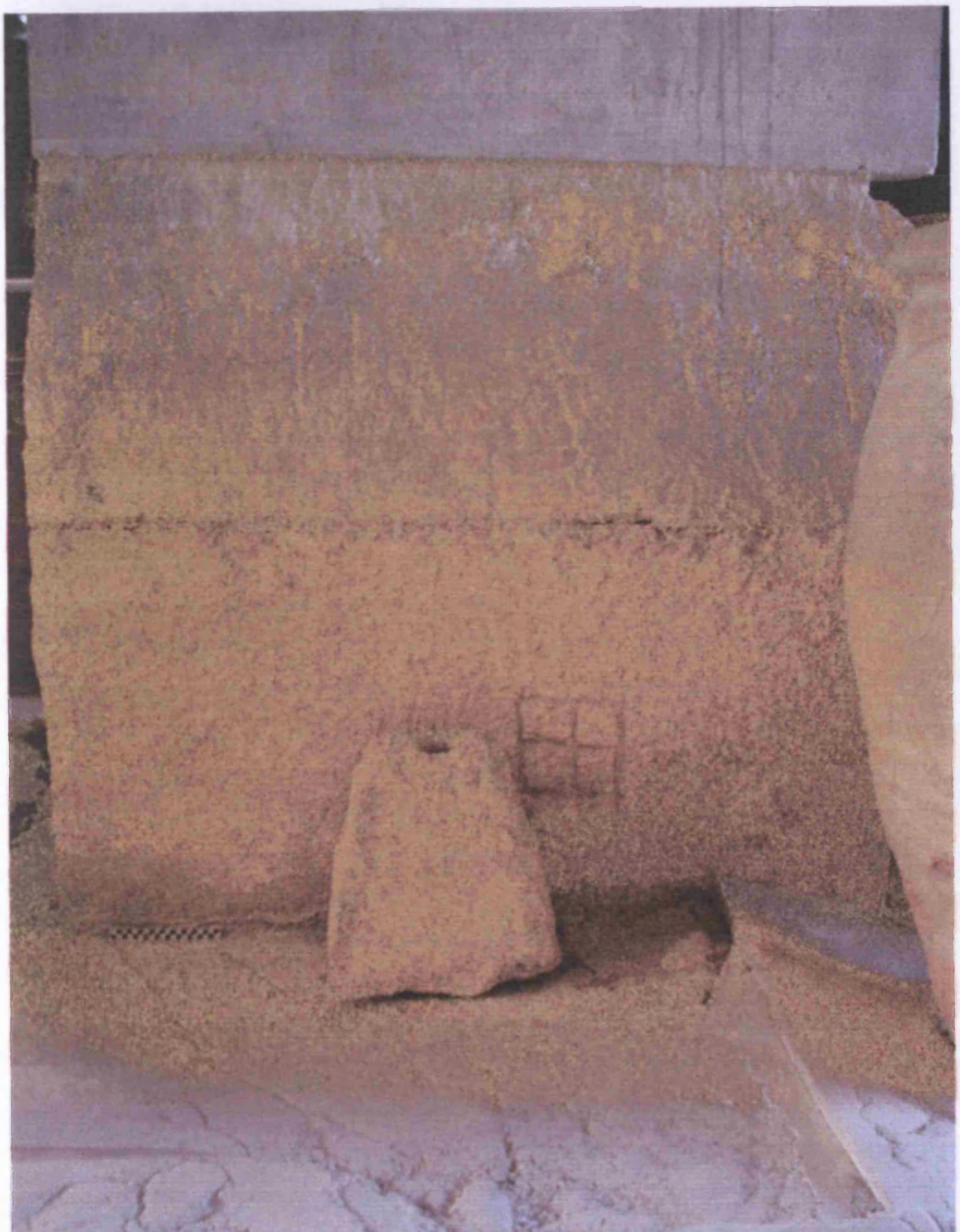


Fig. 5.71: the south jambs of Magazine XI

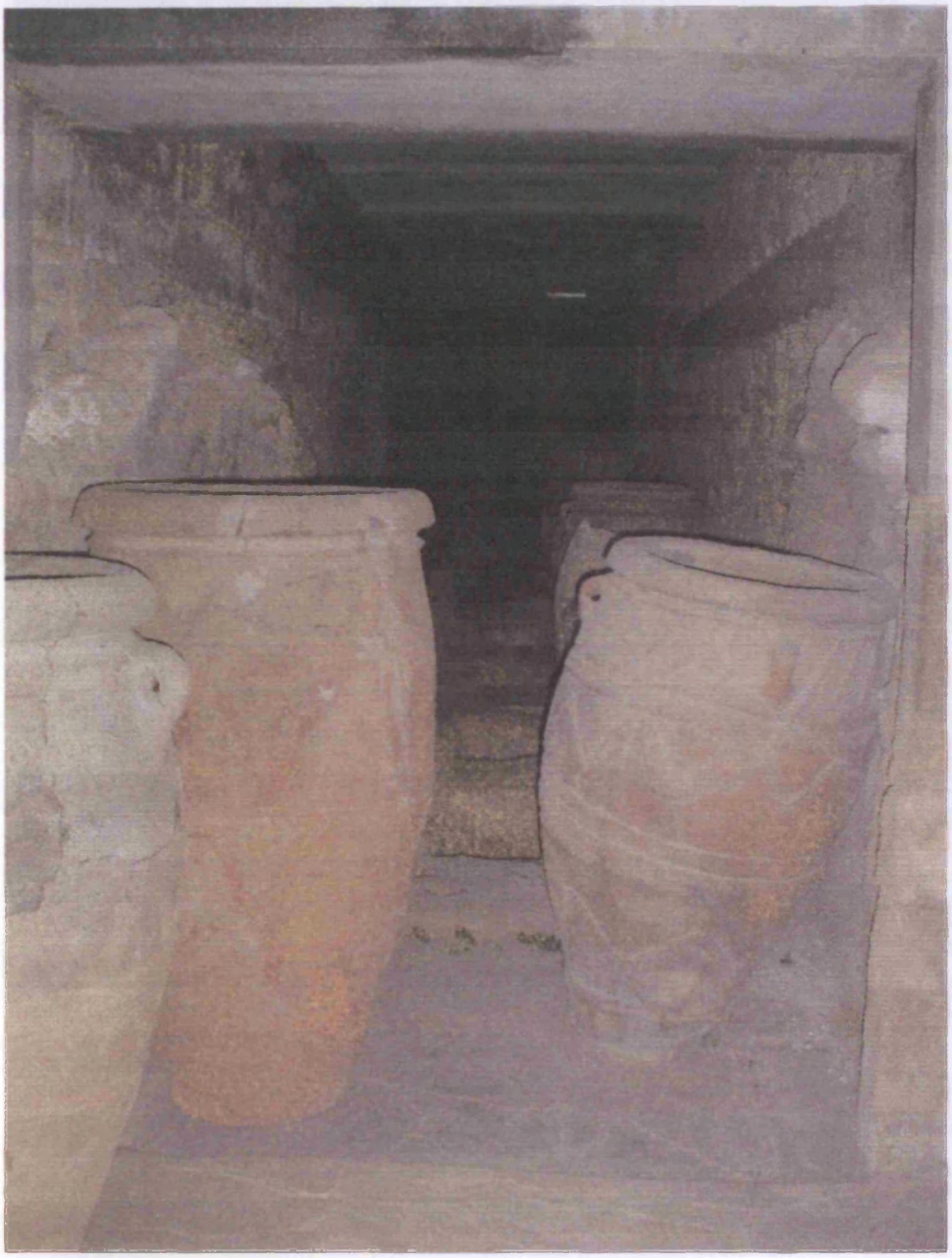


Fig. 5.72: general view of Magazine XI

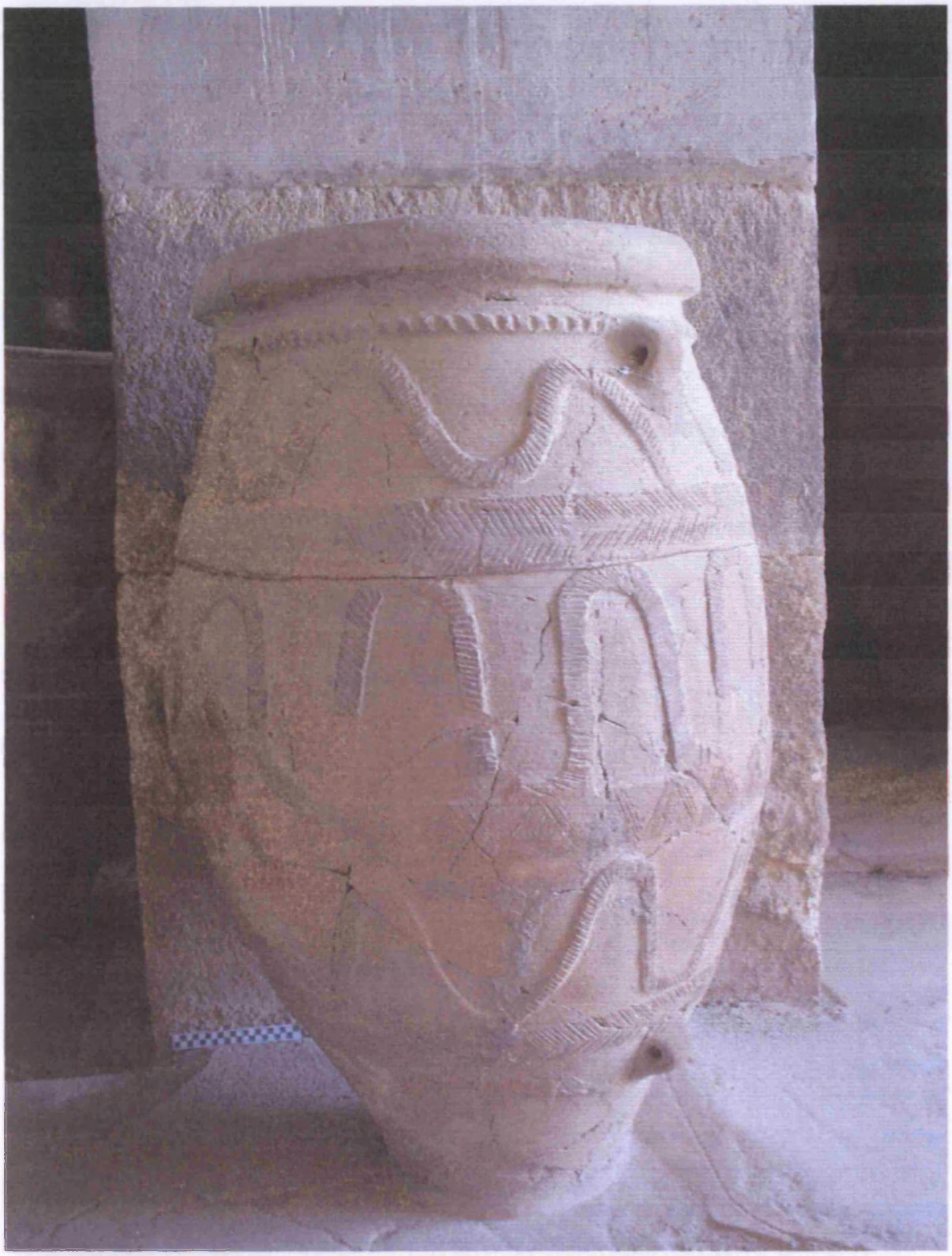


Fig.5.73: the south jamb of Magazine XII

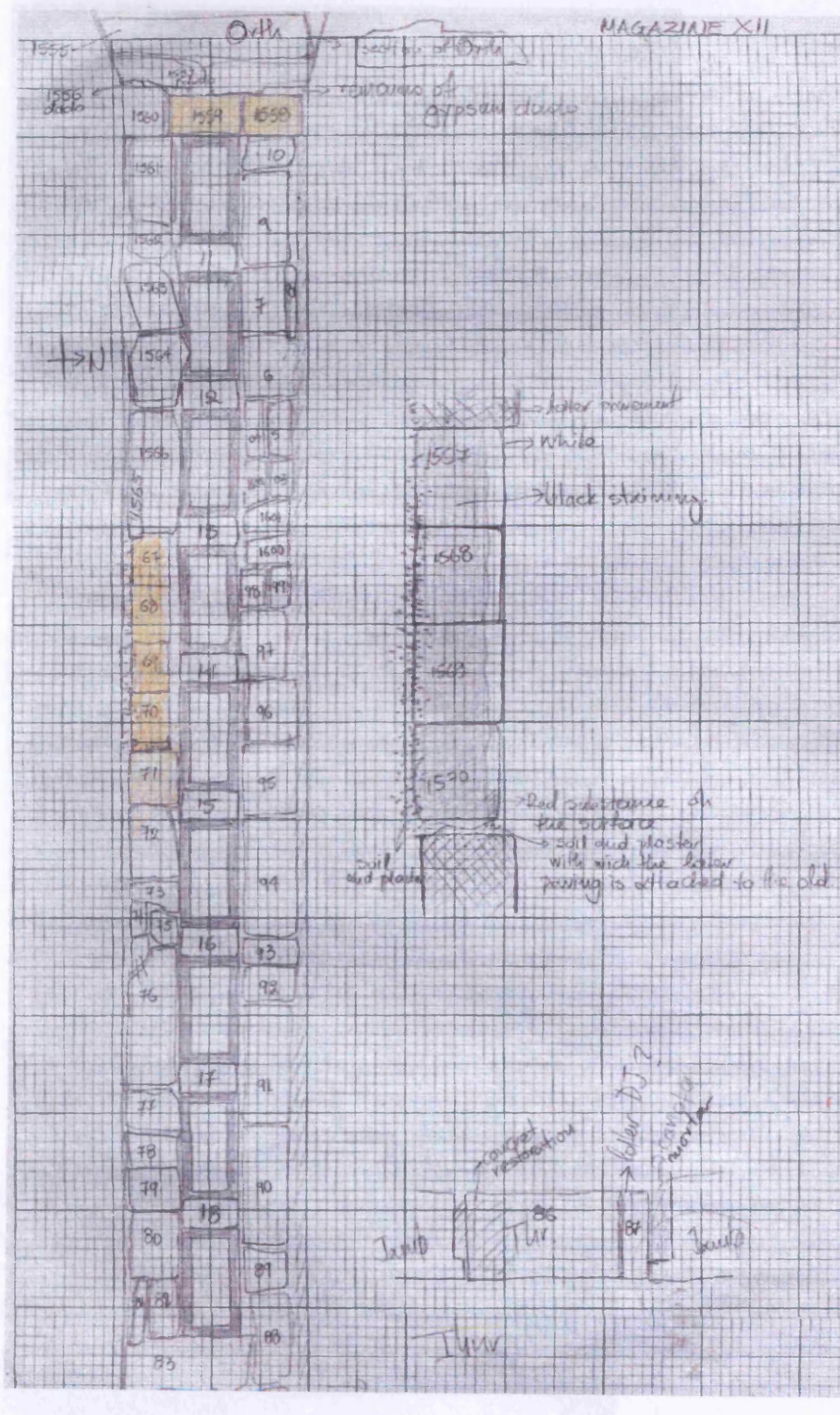


Fig. 5.74: sketch of the floor of Magazine XII

Fig. 5.75: mason's mark in Magazine XII

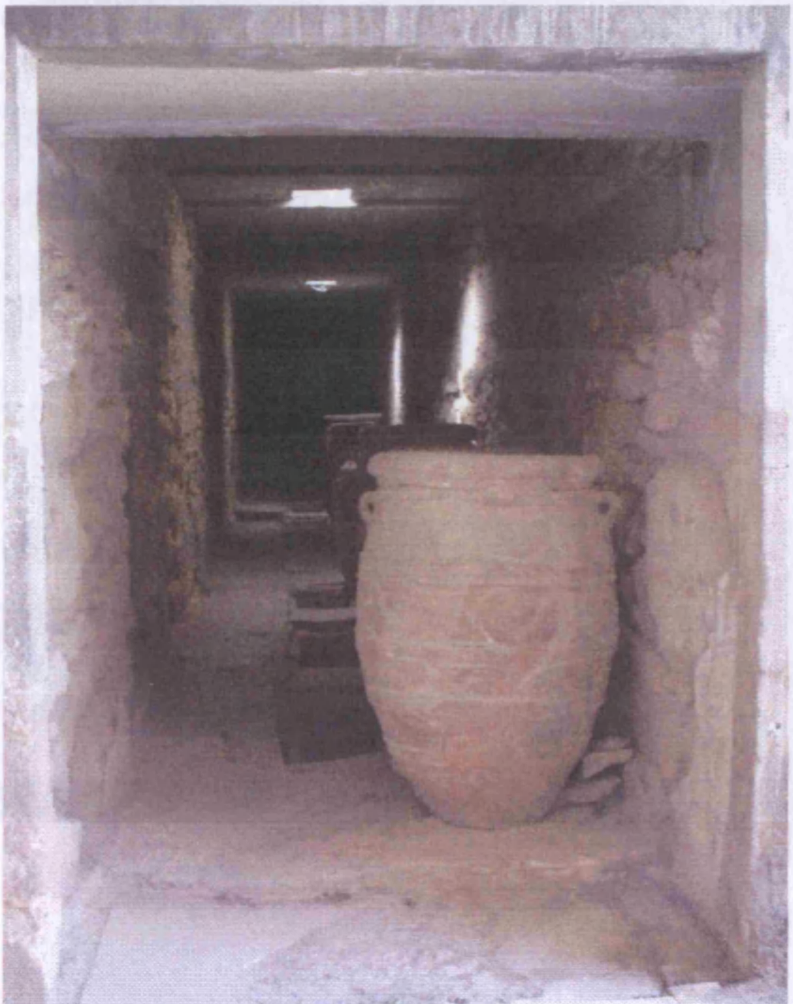


Fig. 5.76: general view of Magazine XII

Fig. 5.77: the south jamb of Magazine XIII

Fig. 5.78: the north jamb of Magazine XIII

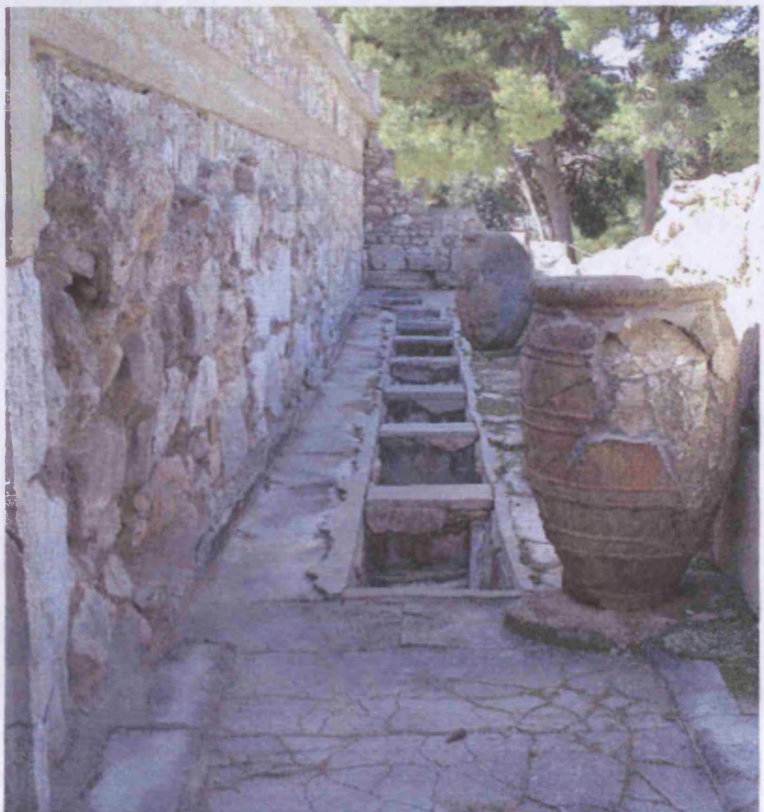


Fig: 4.79: magazine XIII

Fig: 5.80: cist lining sealed with lead sheet

Fig. 5.81: wall dadoes against the south wall of Magazine XIII and in front of a reused block with a gate mason's mark

Fig. 5.82: general view of Magazines XIV-XVI

Fig. 5.83: wall dado remains along the south wall of the Long Gallery north of Magazine XIII

Fig. 5.315: the staircase from Room 2 to 75, with gypsum piers on either side

Fig. 5.316: the south bench and wall dadoes in Room 2

Fig. 5.317: the east bench in Room 2

Fig. 5.318: Staircase 75 from east

Fig. 5.319: the east and part of the south (on the right) bench in Room 75

Fig. 5.320: general view of Corridor 71, Latrine 68 and Magazine 69, from south

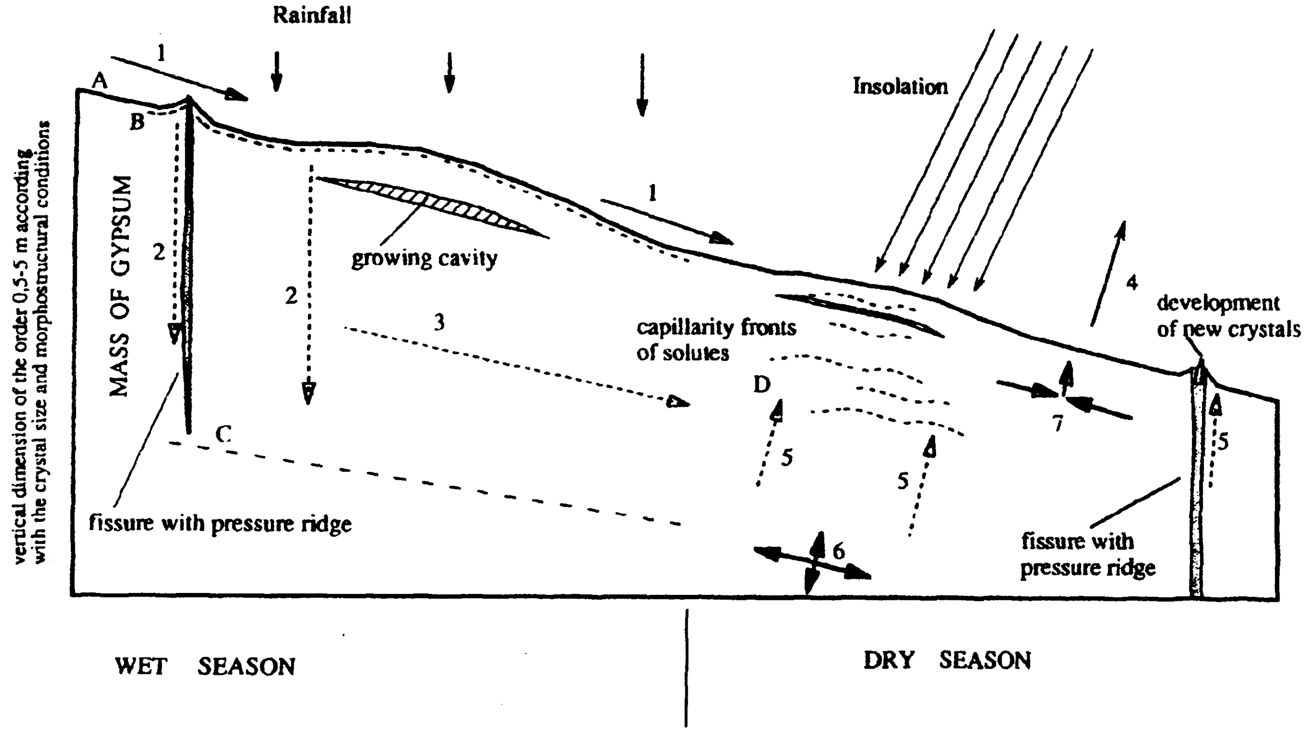


Fig. 7.71: Sketch of the main processes occurring inside the outer gypsum layer during the wet (winter) and the dry (summer) seasons, after Macaluso and Sauro 1998, 2003.

The rainfall starts an overland flow and the water dissolves the gypsum on the surface **A** while part of the water solution manages to penetrate inside the pores of the rock. The solution reaches saturation (with $CaSO_4$) on the surface or a few millimetres inside the rock (the **B** line can be considered a saturation front). The solution continues to penetrate both inside the pores and in the fissures **(2)** reaching a front of porosity water **C**. Water may also flow laterally **(3)**. During the dry season the solution looses water by evaporation **(4)**. The inner solution becomes oversaturated and moves be capillarity towards the surface **(5)**. In the **D** zone there is a precipitation of gypsum which results in the increase of the crystals size or the development of new crystals. In the fissures filled with the fine grained materials new gypsum crystals may develop. The mass transfer from the inner towards the outmost zone results in pressure relaxation **(6)** in the zone **C** and in pressure increase **(7)** in the **D** zone. This mechanism represents a way of mass transfer from the outmost gypsum layer (very thin due to high solubility of gypsum) towards a more inner gypsum layer. The thickness of this layer is probably related to the grain size of the gypsum and ranges between few centimetres (alabastrine gypsum and gypsarenites) and a few metres (macrocrystalline gypsum consisting of very large crystals).

Table 7.3: Classification of the major weathering forms that that have been identified on Minoan gypsum

	Massive selenite		Banded selenite		Nod and Lent Selenite		Laminated	Micro-environment		
	original texture	dehydrated	original texture	dehydrated	original texture	dehydrated	org.tx/deh	Outdoors	Sheltered	Restored
Karen forms	x	xxx	xx	xxx	xx	xxx	xxx	x		
Granular Des	xxx	x	xx	x	x			x		
Loss of trans/ncy	xxx		xxx		xx			x	x	x
Gypsum crust	xx	xxx	xx	xx	xx	xx	xx	x	x	x
"Weathring crust"	xx	xxx	xx	xxx	xx	xxx	xxx	x		
Str/Fiss	x	x	xx	xx	xxx	xxx	xxx	x	x	x
N-Str/Fiss	x	xx	x	xx	x	xx	xx	x	x	x
Crumbling	x	xxx	x	xx	x	xx	x	x		
Efflor/suflor						x	xx		x	x
Exfoliation						x	xx		x	x
Biodeterioration	xxx	xxx	xx	xx	xx	xx	x	x		
Higher Plants	x	x	x	x	x	x	x	x		
Coloration		xx		xx		xx	xx	x	x	x
Deformation	x	xx						x	x	x

x: slight
xx: moderate
xxx: severe

"Gypsum in Minoan Architecture: Exploitation, Utilisation and Weathering of a Prestige Stone"

Vol.III: Appendixes

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University College London

PhD

Appendix 3: Catalogue

Knossos: architectural gypsum catalogue

	Site	Location	Function	Height	Length	Width	Date
1	KN	W.Porch	As	1.07	1.5	0.38	OP
2	KN	W.Porch	As	1.07	1.6	0.36	OP
3	KN	W.Porch	As	1.54	0.94	30	NP
4	KN	W.Porch	CB	20+		D 1,30	NP
5	KN	W.Porch	AS	54	1.3	0.63	NP
6	KN	W.Porch	Jamp	0.3	1.4	1.35	NP
7	KN	W.Porch	DJ	0.2	1.25	0.38	NP
8	KN	W.Porch	Thr	1.3	0.47	0.05	NP
9	KN	W.Porch	Thr	1.3	2.5	0.05	NP
10	KN	W.Porch	Jamp	0.3	0.8	1.5	NP
11	KN	W.Porch	Jamp	0.75	1.04	0.18	NP
12	KN	W.Porch	Jamp	0.3	0.75	1	NP
13	KN	Room 12	DJ	0.3	1.25	0.25	NP
14	KN	Room 12	DJ	0.3	1.25	0.25	NP
15	KN	W.Porch	Thr	1.42	1.62	0.1	NP
16	KN	W.Porch	Thr	1.42	1.55	0.1	NP
17	KN	W.Porch	DJ	0.3	1.57	0.38	NP
18	KN	W.Porch	FS	1.42	0.94	0.05	NP
19	KN	W.Porch	FS	1.7	0.92	0.05	NP
20	KN	W.Porch	FS	1.46	0.98	0.05	NP
21	KN	W.Porch	FS	0.79	0.98	0.05	NP
22	KN	W.Porch	FS	0.98	0.98	0.05	NP
23	KN	W.Porch	FS	0.7	0.99	0.05	NP
24	KN	W.Porch	FS	1.2	0.99	0.05	NP
25	KN	W.Porch	FS	1	0.99	0.05	NP
26	KN	W.Porch	FS	0.89	0.99	0.05	NP
27	KN	W.Porch	FS	1.25	0.99	0.05	NP
28	KN	W.Porch	FS	0.9	0.99	0.05	NP
29	KN	W.Porch	FS	0.93	0.99	0.05	NP
30	KN	W.Porch	FS	0.91	0.99	0.05	NP
31	KN	W.Porch	FS	1.4	0.99	0.05	NP
32	KN	W.Porch	FS	1.4	0.99	0.05	NP
33	KN	W.Porch	FS	1.1	1.04	0.05	NP
34	KN	W.Porch	FS	1.15	1	0.05	NP
35	KN	W.Porch	FS	0.94	1.01	0.05	NP
36	KN	W.Porch	FS	1.6	1.01	0.05	NP
37	KN	W.Porch	FS	0.72	1	0.05	NP
38	KN	W.Porch	FS	0.94	1	0.05	NP
39	KN	W.Porch	FS	0.98	1	0.05	NP
40	KN	Room 12	As	1.12	0.95	0,44+	NP
41	KN	Room 12	As	0.91	0.93	0,25+	NP
42	KN	Room 13	As	0.62	0.4	0,24+	NP
43	KN	Room 13	As	0.87	0.122	0.4	NP
44	KN	Room 13	As	1.00	0.64	0,23+	NP
45	KN	Room 13	As	DR	DR	DR	NP
46	KN	Room 12	As	DR	DR	DR	NP
47	KN	Room 12	As	DR	DR	DR	NP
48	KN	Cor of Pro	As	0.55	0.6	0.6	NP
49	KN	Cor of Pro	FS	1.06	1.17	0.05	NP
50	KN	Cor of Pro	FS	1.07	1.61	0.05	NP
51	KN	Cor of Pro	FS	1.07	1.67	0.05	NP
52	KN	Cor of Pro	FS	1.09	1.28	0.05	NP
53	KN	Cor of Pro	FS	1.04	1.39	0.05	NP
54	KN	Cor of Pro	FS	1.04	1.51	0.05	NP
55	KN	Cor of Pro	FS	1.04	1	0.05	NP
56	KN	Cor of Pro	FS	1.04	1.61	0.05	NP

	Site	Location	Function	Height	Length	Width	Date
57	KN	Cor of Pro	FS	1.02	1.49	0.05	NP
58	KN	Cor of Pro	FS	1.02	1.7	0.05	NP
59	KN	Cor of Pro	FS	1.03	1.19	0.05	NP
60	KN	Cor of Pro	FS	1.03	0.57	0.05	NP
61	KN	S-W Corner	As	0.7	1.28	0.64	NP
62	KN	S-W Corner	As	0.59	0.28	0.9	NP
63	KN	S-W Corner	As	0.7	0.75	0.84	NP
64	KN	S-W Corner	As	0.53	1.04	0.75	NP
65	KN	S-W Corner	As	0.8	1.38	1.15	NP
66	KN	S-W Corner	As	0.8	1.4	0.71	NP
67	KN	S-W Corner	As	0,5+	0.65	0.49	NP
68	KN	S-W Corner	As	0.85	1.3	0.8	NP
69	KN	S-W Corner	As	0,57+	1.35	0.79	NP
70	KN	S-W Corner	As	1.04	1.04	0.98	NP
71	KN	S-W Corner	As	DR	DR	DR	NP
72	KN	S-W Corner	As	0.8	0.93	0.64	NP
73	KN	S-W Corner	As	0.55	0.75	0.6	NP
74	KN	S-W Corner	As	0.85	1.04	0.57	NP
75	KN	S-W Corner	As	0.85	0.7	0.49	NP
76	KN	S-W Corner	As	0.25	0.6	0.65	NP
77	KN	S-W Corner	As	0.6	0.9	0.64	NP
78	KN	S-W Corner	As	0.73	0.93	0.43	NP
79	KN	S-W Corner	AS	0.7	0.65	0.2	NP
80	KN	S-W Corner	CB	0.3	0.27	0.4	NP
81	KN	S-W Corner	As	0.33	0.46	0.45	NP
82	KN	Room 3	As	0.53	0.75	0.5	NP
83	KN	Room 3	As	0,10+	0.6	0.75	NP
84	KN	Room 3	As	0,25+	0.72	0.6	NP
85	KN	Room 3	As	0,30+	0.5	0.4	NP
86	KN	Room 3	As	0.85	1.25	1.03	NP
87	KN	Room 3	As	0.84	1.25	1.05	NP
88	KN	Room 3	As	0.83	1.05	1.35	NP
89	KN	Room 3	As	0.6	0,4+	0.45	NP
90	KN	Room 3	As	0.7	0.88	1	NP
91	KN	Ter. Baseme	As	0.32	0.52	0.56	NP
92	KN	Ter. Baseme	As	0.4	1	0.94	NP
93	KN	Ter. Baseme	As	0.32	0.7	0.55	NP
94	KN	Ter. Baseme	As	0.58	0.5	0.95	NP
95	KN	Ter. Baseme	As	0.62	0.75	0.7	NP
96	KN	Ter. Baseme	As	DR	DR	DR	NP
97	KN	Ter. Baseme	As	0.15	0.65	0.58	NP
98	KN	Ter. Baseme	As	DR	DR	DR	NP
99	KN	South Wall	As	0.5	0.65	0.73	NP
100	KN	South Wall	As	0.4	0.55	0.63	NP
101	KN	South Wall	As	0.65	0.92	0.78	NP
102	KN	South Wall	ScS	0.12	0.63	0.5	NP
103	KN	South Wall	As	0.4	0.75	0.55	NP
104	KN	South Wall	As	0.4	0.73	0.8	NP
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106	KN	South Wall	As	0.63	0.88	0.59	NP
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109	KN	South Wall	As	0.74	1.6	0.8	NP
110	KN	South Wall	As	0.79	1.57	0.95	NP
111	KN	South Wall	As	0.83	0.64	1.3	NP
112	KN	South Wall	As	0.8	1.49	0.89	NP

	Site	Location	Function	Height	Length	Width	Date
113	KN	South Wall	As	0.8	1.3	0.5	NP
114	KN	South Wall	As	0.59	1.08	0.52	NP
115	KN	South Wall	As	0.6	1.23	0.45	NP
116	KN	South Wall	As	0.49	1	0.7	NP
117	KN	South Wall	As	0.8	0.8	0.5	NP
118	KN	South Wall	As	0.82	1.44	0.63	NP
119	KN	South Wall	As	0.83	1.31	0.63	NP
120	KN	South Wall	As	0.82	0.92	0.59	NP
121	KN	South Wall	As	DR	DR	0.4	NP
122	KN	South Wall	As	0.21	0.33	0.27	NP
123	KN	South Wall	As	0.86	2.18	0.59	NP
124	KN	South Wall	As	0.84	0.92	0.58	NP
125	KN	South Wall	As	0.34	0.7	0.31	NP
126	KN	South Wall	As	0.33	0.5	0.3	NP
127	KN	South Wall	As	0.82	83/69	0.75	NP
128	KN	)rway of S.Co	DJ	0.3	1.42	0.3	NP
129	KN	)rway of S.Co	DJ	0.3	1.25	0.35	NP
130	KN	)rway of S.Co	DJ	0.3	1.35	0.39	NP
131	KN	)rway of S.Co	Thr	1.4	0.99	0.05	NP
132	KN	)rway of S.Co	Thr	1.4	1	0.05	NP
133	KN	South Corrido	FS	1.25	0.72	0.05	NP
134	KN	South Corrido	FS	1.47	0.74	0.05	NP
135	KN	South Corrido	FS	1.3	0.74	0.05	NP
136	KN	South Corrido	FS	1.5	0.73	0.05	NP
137	KN	South Corrido	FS	1	0.72	0.05	NP
138	KN	South Corrido	FS	1.27	0.71	0.05	NP
139	KN	South Corrido	FS	1.5	0.7	0.05	NP
140	KN	South Porch	FS	0.71	0.84	0.05	NP
141	KN	South Porch	FS	1.07	0.85	0.05	NP
142	KN	South Porch	As	0.63	0.85	1.25	NP
143	KN	South Porch	As	0.72	1.25	0.72	NP
144	KN	South Porch	As	0.84	1.25	1	NP
145	KN	South Porch	As	0.89	1.7	0.5	NP
146	KN	South Porch	As	0.88	0.86	0.55	NP
147	KN	S-E Magazine	As	0.62	DR	DR	NP
148	KN	S-E Magazine	DJ?	0.2	1.3	0.33	NP
149	KN	S-E Magazine	DJ?	0.19	1.3	0.3	NP
150	KN	Room 5	Thr	0.12	1.3	0.56	NP
151	KN	Room 5	?	0.17	0.75	0.68	NP
152	KN	Room 5	As	0.67	1.4	0.96	NP
153	KN	Room 5	As	0.7	1.4	0.76	NP
154	KN	S-E Magazine	As	0.4	0.96	0.58	NP
155	KN	S-E Magazine	As	0.4	0.92	0.73	NP
156	KN	d of Cor. of P	ScS	0.16	2.84	0.45	NP
157	KN	d of Cor. of P	ScS	0.16	2.84	0.45	NP
158	KN	d of Cor. of P	FS	0.97	0.9	0.45	NP
159	KN	d of Cor. of P	FS	0.73	0.9	0.45	NP
160	KN	d of Cor. of P	FS	0.9	0.9	0.45	NP
161	KN	d of Cor. of P	FS	1.01	0.9	0.45	NP
162	KN	d of Cor. of P	FS	1.74	0.9	0.45	NP
163	KN	d of Cor. of P	FS	1.33	0.9	0.45	NP
164	KN	d of Cor. of P	FS	1.02	0.9	0.45	NP
165	KN	d of Cor. of P	FS	1	0.9	0.45	NP
166	KN	West of 9	DJ	0.27	0.8	0.34	NP
167	KN	West of 9	As	0.78	1.2	0.37	NP
168	KN	Clay Bath	As	0.54	0.81	0.96	NP

	Site	Location	Function	Height	Length	Width	Date
169	KN	Clay Bath	As	0.66	1,40/1,44	0.81	NP
170	KN	Clay Bath	DJ	0.2	0.97	0.4	NP
171	KN	Clay Bath	DJ	0.18	1.25	0.44	NP
172	KN	;. of Clay Bat	DJ	0.15	0.77	0.68	NP
173	KN	;. of Clay Bat	DJ	0.3	0.94	0.53	NP
174	KN	uth Propylae	AS	0.35	0.99	0.55	NP
175	KN	uth Propylae	AS	DR	DR	DR	NP
176	KN	uth Propylae	AS	0.33	1.55	0.78	NP
177	KN	uth Propylae	AS	0.76	0.92	0.92	NP
178	KN	uth Propylae	AS	0.33	0.8	0.4	NP
179	KN	uth Propylae	AS	0.25	0.96	0.66	NP
180	KN	uth Propylae	AS	0.22	0.8	0.7	NP
181	KN	uth Propylae	?	0.23	0.76	0.53	NP
182	KN	uth Propylae	?	0.25	0.92	0.36	NP
183	KN	uth Propylae	?	0.2	1.25	0.5	NP
184	KN	uth Propylae	?	0.34	0.43	0.36	NP
185	KN	uth Propylae	?	0.13	0.8	0.33	NP
186	KN	uth Propylae	?	0.36	1.3	0.38	NP
187	KN	uth Propylae	CB	0.24	DR	DR	NP
188	KN	uth Propylae	ScS	0.16	0.71	0.39	NP
189	KN	uth Propylae	ScS	0.15	4.22	0.65	NP
190	KN	uth Propylae	ScS	0.15	4.22	0.45	NP
191	KN	uth Propylae	DJ	0.25	1.15	0.65	NP
192	KN	uth Propylae	DJ	0.25	1.08	0.5	NP
193	KN	uth Propylae	DJ	0.25	1.08	0.5	NP
194	KN	uth Propylae	DJ	0.25	1.08	0.5	NP
195	KN	uth Propylae	DJ	0.25	1.08	0.5	NP
196	KN	uth Propylae	DJ	0.25	1.08	0.5	NP
197	KN	uth Propylae	Thr	0.08	1.27	0.82	NP
198	KN	uth Propylae	Thr	0.1	2.35	1.1	NP
199	KN	uth Propylae	Thr	0.1	1.28	1.1	NP
200	KN	uth Propylae	DJ	0.15	1.34	0.51	NP
201	KN	Room 4	Jamp	0.69	0.76	0.55	NP
202	KN	Room 4	Jamp	0.69	0.48	0.48	NP
203	KN	Room 4	ScS	0.13	0.87	0.36	NP
204	KN	Room 4	ScS	0.13	0.87	0.39	NP
205	KN	Room 4	Thr	0.1	1.2	1	NP
206	KN	End of Cor. 1	AS	0.54	1.62	1.16	NP
207	KN	outh of Room	AS	0.3	0.66	0.47	NP
208	KN	outh of Room	AS	0.32	1.17	0.55	NP
209	KN	outh of Room	DJ	0.28	1.07	0.52	NP
210	KN	Room 17	DJ	0.34	0.88	0.33	NP
211	KN	Room 17	AS	0.1	1.03	0.81	NP
212	KN	Room 17	AS	X	0.92	0.82	NP
213	KN	Room 17	AS	0.08	1.3	0.8	NP
214	KN	Room 17	DJ	0.1	1.3	0.45	NP
215	KN	Room 17	AS	0.1	0.8	0.27	NP
216	KN	Room 17	AS	0.1	0.77	0.5	NP
217	KN	Room 18	AS	0.1	0.55	0.4	NP
218	KN	Room 114	FS	0.5	0.45	0.05	NP
219	KN	Room 114	FS	0.5	0.69	0.05	NP
220	KN	Room 114	ScS	0.26	2.73	0.26	NP
221	KN	Room 114	ScS	0.26	2.73	0.26	NP
222	KN	Room 114	ScS	0.26	2.73	0.26	NP
223	KN	Room 114	ScS	0.26	2.73	0.26	NP
224	KN	Room 114	ScS	0.26	2.73	0.26	NP

	Site	Location	Function	Height	Length	Width	Date
225	KN	Room 114	ScS	0.26	2.73	0.26	NP
226	KN	Room 114	ScS	0.35	2.73	0.35	NP
227	KN	Room 114	Pill	1	1	1	NP
228	KN	Room 114	Pill	1	1	1	NP
229	KN	Room 114	DJ	0.47	1.08	0.47	NP
230	KN	Room 114	DJ	0.35	1.08	0.35	NP
231	KN	Room 114	DJ	0.22	1.08	0.22	NP
232	KN	l. of Room 11	DJ	0.22	0.81	0.22	NP
233	KN	l. of Room 11	FS	0.8	0.95	0.05	NP
234	KN	l. of Room 11	FS	0.5	1.1	0.05	NP
235	KN	l. of Room 11	FS	0.75	1.1	0.05	NP
236	KN	l. of Room 11	FS	0.57	1.2	0.05	NP
237	KN	l. of Room 11	FS	0.8	1.28	0.05	NP
238	KN	. of Room 11	FS	0.67	0.74	0.05	NP
239	KN	. of Room 11	FS	0.63	0.74	0.05	NP
240	KN	. of Room 11	FS	0.56	0.65	0.05	NP
241	KN	. of Room 11	FS	0.58	0.62	0.05	NP
242	KN	. of Room 11	FS	0.64	0.64	0.05	NP
243	KN	. of Room 11	FS	0.62	0.64	0.05	NP
244	KN	. of Room 11	FS	0.83	0.86	0.05	NP
245	KN	. of Room 11	FS	0.41	0.83	0.05	NP
246	KN	. of Room 11	DJ	0.23	0.65	0.23	NP
247	KN	. of Room 11	DJ	0.23	0.65	0.23	NP
248	KN	. of Room 11	Thr	0.55	0.75	0.55	NP
249	KN	l. of Room 11	FS	0.67	0.9	0.05	NP
250	KN	l. of Room 11	FS	0.78	0.88	0.05	NP
251	KN	l. of Room 11	FS	0.8	0.96	0.05	NP
252	KN	l. of Room 11	FS	0.39	0.94	0.05	NP
253	KN	l. of Room 11	Thr	1.2	0.94	1.2	NP
254	KN	Room 112a	DJ	0.65	1.15	0.65	NP
255	KN	Room 112a	DJ	0.14	1.17	0.14	NP
256	KN	Room 112a	Thr	0.8	1.16	0.8	NP
257	KN	Room 112a	DJ	0.8	1.16	0.8	NP
258	KN	Room 112a	FS	0.47	0.71	0.05	NP
259	KN	Room 112a	FS	0.37	0.66	0.05	NP
260	KN	Room 112a	FS	0.6	0.63	0.05	NP
261	KN	Room 112a	FS	0.33	0.65	0.05	NP
262	KN	Room 112a	FS	0.33	0.6	0.05	NP
263	KN	Room 112a	FS	0.4	0.6	0.05	NP
264	KN	Room 112a	FS	0.48	0.62	0.05	NP
265	KN	Room 112a	DJ	0.15	0.77	0.15	NP
266	KN	Room 112a	DJ	0.32	0.94	0.32	NP
267	KN	Room 111	DJ	0.15	0.49	0.15	NP
268	KN	Room 111	DJ	0.15	0.49	0.15	NP
269	KN	Room 113	DJ	0.15	0.85	0.15	NP
270	KN	Room 113	DJ	0.4	1.4	0.4	NP
271	KN	Room 113	Thr	0.63	0.83	0.63	NP
272	KN	Room 113	AS	0.3	0.5	0.3	NP
273	KN	Room 113	FS	0.52	0.82	0.05	NP
274	KN	Room 113	FS	0.9	0.98	0.05	NP
275	KN	Room 113	ScS	0.28	0.93	0.28	NP
276	KN	Room 113	ScS	0.29	0.94	0.29	NP
277	KN	Room 113	ScS	0.92	0.74	0.92	NP
278	KN	Room 113	ScS	0.52	0.72	0.52	NP
279	KN	Room 113	FS	0.45	1.44	0.05	NP
280	KN	Room 113	FS	0.81	1.44	0.05	NP

	Site	Location	Function	Height	Length	Width	Date
281	KN	Room 113	FS	0.93	1.44	0.05	NP
282	KN	Room 113	FS	0.93	0.75	0.05	NP
283	KN	Room 113	FS	0.69	1.24	0.05	NP
284	KN	Room 113	Pill	0.92	0.54	0.5	NP
285	KN	Room 113	WR	0.82	0.92	0.04	NP
286	KN	Room 113	WR	0.8	0.88	0.04	NP
287	KN	Room 113	WR	0.74	0.62	0.04	NP
288	KN	Room 113	WR	0.72	0.8	0.04	NP
289	KN	Room 113	WR	0.58	0.69	0.04	NP
290	KN	Room 113	WR	0.59	0.83	0.04	NP
291	KN	Room 113	WR	0.59	0.69	0.04	NP
292	KN	Room 113	WR	1.14	0.98	0.04	NP
293	KN	Room 113	WR	1.14	0.82	0.04	NP
294	KN	Room 113	WR	1.14	0.87	0.04	NP
295	KN	Room 113	WR	0.84	1.04	0.04	NP
296	KN	Room 113	WR	0.94	1.04	0.04	NP
297	KN	Room 113	WR	0.72	0.96	0.04	NP
298	KN	Room 113	WR	0.72	1	0.04	NP
299	KN	Room 113	WR	0.39	1.11	0.04	NP
300	KN	of Room 11:	FS	0.92	0.46	0.05	NP
301	KN	of Room 11:	DJ	0.16	1.16	0.28	NP
302	KN	of Room 11:	DJ	0.14	1.06	0.21	NP
303	KN	of Room 11:	DJ	0.1	1.08	0.32	NP
304	KN	of Room 11:	AS	0.43	0.53	0.31	NP
305	KN	of Room 11:	AS	0.93	1.05	0.97	NP
306	KN	of Room 11:	FS	0.5	0.5	0.05	NP
307	KN	Corridor 110	DJ	0.2	0.7	0.23	NP
308	KN	Corridor 110	Thr	0.72	0.71	0.05	NP
309	KN	Corridor 110	DJ	0.13	0.76	0.19	NP
310	KN	Corridor 110	FS	1.1	1.05	0.05	NP
311	KN	Corridor 110	FS	0.85	1.53	0.025	NP
312	KN	Corridor 110	FS	1.05	1.5	0.05	NP
313	KN	Corridor 110	FS	0.31	0.53	0.05	NP
314	KN	Corridor 110	FS	0.66	0.53	0.05	NP
315	KN	Corridor 110	FS	0.24	1.06	0.05	NP
316	KN	Corridor 110	FS	1.01	1.25	0.05	NP
317	KN	. of Room 10	AS	0.81	1.04	0.81	NP
318	KN	. of Room 10	AS	0.83	1.27	0.83	NP
319	KN	Corridor 107	FS	0.65	0.84	0.05	NP
320	KN	Corridor 107	FS	0.65	0.58	0.05	NP
321	KN	Corridor 107	FS	0.62	0.55	0.05	NP
322	KN	Corridor 107	FS	0.64	0.62	0.05	NP
323	KN	Corridor 107	FS	0.59	0.69	0.05	NP
324	KN	Corridor 107	FS	0.55	0.4	0.05	NP
325	KN	Corridor 107	FS	0.5	0.72	0.05	NP
326	KN	Corridor 107	FS	0.5	0.46	0.05	NP
327	KN	Room 108	Thr	0.3	0.62	0.3	NP
328	KN	Room 108	Thr	0.35	0.61	0.35	NP
329	KN	Room 108	Thr	0.32	0.64	0.32	NP
330	KN	Room 108	FS	0.8	0.82	0.05	NP
331	KN	Room 108	FS	1.07	0.91	0.05	NP
332	KN	Room 108	FS	1.07	0.87	0.05	NP
333	KN	Room 108	FS	0.89	0.81	0.05	NP
334	KN	Room 108	WR	0.92	0.98	0.07	NP
335	KN	Room 108	WR	0.27	0.9	0.07	NP
336	KN	Room 108	WR	2	0.86	0.07	NP

	Site	Location	Function	Height	Length	Width	Date
337	KN	Room 108	WR	0.62	1.07	0.07	NP
338	KN	Room 108	WR	0.71	1.04	0.07	NP
339	KN	Room 108	WR	0.65	0.86	0.07	NP
340	KN	Room 108	WR	0.75	0.82	0.07	NP
341	KN	Corridor 105	FS	0.71	0.62	0.05	NP
342	KN	Corridor 105	FS	0.65	0.5	0.05	NP
343	KN	Corridor 105	FS	0.68	0.6	0.05	NP
344	KN	Corridor 105	FS	0.83	0.67	0.05	NP
345	KN	Corridor 105	FS	0.75	0.66	0.05	NP
346	KN	Corridor 105	FS	0.74	0.65	0.05	NP
347	KN	Corridor 105	FS	0.75	0.65	0.05	NP
348	KN	Corridor 105	FS	0.64	0.67	0.05	NP
349	KN	Corridor 105	FS	0.53	0.7	0.05	NP
350	KN	. from 105 to	FS	0.78	0.24	0.05	NP
351	KN	. from 105 to	FS	0.74	0.23	0.05	NP
352	KN	. from 105 to	FS	0.5	0.8	0.05	NP
353	KN	. from 105 to	FS	0.52	0.8	0.05	NP
354	KN	. from 105 to	FS	0.28	0.8	0.05	NP
355	KN	. from 105 to	FS	0.2	0.79	0.05	NP
356	KN	. from 105 to	FS	0.6	0.76	0.05	NP
357	KN	. from 105 to	DJ	0.07	0.63	0.15	NP
358	KN	. from 105 to	DJ	0.07	0.64	0.17	NP
359	KN	. from 105 to	DJ	0.07	0.68	0.16	NP
360	KN	. from 105 to	FS	0.67	0.92	0.05	NP
361	KN	. from 105 to	FS	0.65	0.92	0.05	NP
362	KN	. from 105 to	FS	0.49	0.92	0.05	NP
363	KN	Room 106	FS	0.4	0.43	0.05	NP
364	KN	Room 106	WR	2	0.82	0.025	NP
365	KN	Room 106	WR	2	0.82	0.025	NP
366	KN	Room 106	WR	2	0.8	0.025	NP
367	KN	Room 106	WR	2	0.8	0.025	NP
368	KN	Room 106	WR	2	1.02	0.025	NP
369	KN	. from 105 to	BS	0.96	0.51	0.08	NP
370	KN	. from 105 to	BS	1	0.52	0.1	NP
371	KN	l. of Room 10	ScS	0.2	0.72	0.3	NP
372	KN	l. of Room 10	ScS	0.15	0.74	0.3	NP
373	KN	l. of Room 10	ScS	0.15	0.7	0.3	NP
374	KN	l. of Room 10	ScS	0.1	0.67	0.3	NP
375	KN	l. of Room 10	AS	0.64	0.95	0,66/0,26	NP
376	KN	l. of Room 10	AS	6	0.85	0.6	NP
377	KN	l. of Room 10	FS	0.96	0.87	0.08	NP
378	KN	l. of Room 10	DJ	0.26	0.75	0.37	NP
379	KN	l. of Room 10	DJ	0.09	0.72	0.24	NP
380	KN	l. of Room 10	DJ	0.18	0.72	0.25	NP
381	KN	l. of Room 10	DJ	0.3	0.8	0.28	NP
382	KN	l. of Room 10	DJ	0.29	0.79	0.22	NP
383	KN	l. of Room 10	DJ	0.19	1.05	0.23	NP
384	KN	l. of Room 10	DJ	0.32	1.07	0.32	NP
385	KN	l. of Room 10	Thr	0.06	0.88	0.73	NP
386	KN	l. of Room 10	Thr	0.06	0.92	0.73	NP
387	KN	l. of Room 10	Thr	0.06	1.06	0.77	NP
388	KN	l. of Room 10	Thr	0.06	1.1	0.98	NP
389	KN	f the Stone B	DJ	0.13	0.92	0.3	NP
390	KN	f the Stone B	DJ	0.13	0.92	0.32	NP
391	KN	f the Stone B	DJ	0.13	0.92	0.3	NP
392	KN	f the Stone B	DJ	0.13	0.92	0.3	NP

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	Site	Location	Function	Height	Length	Width	Date
393	KN	f the Stone B	Thr	0.06	1.15	0.92	NP
394	KN	f the Stone B	BS	0.05	1.74	0.42	NP
395	KN	f the Stone B	BS	0.32	1.5	0.35	NP
396	KN	f the Stone B	DJ	0.12	0.65	0.29	NP
397	KN	f the Stone B	DJ	0.12	0.63	0.27	NP
398	KN	ɔer E-W Corr	DJ	0.12	1.08	0.24	NP
399	KN	ɔer E-W Corr	DJ	0.12	1.08	0.24	NP
400	KN	Jpper Corridc	Thr	0.06	1.04	1.15	NP
401	KN	Jpper Corridc	DJ	0.12	0.9	0.21	NP
402	KN	Jpper Corridc	DJ	0.12	0.9	0.74	NP
403	KN	ɘasury of Shr	Thr	0.06	0.93	1.15	NP
404	KN	Pier	Orth	0.8	0.92	0.83	NP
405	KN	ɘasury of Shr	DJ	0.12	0.9	0.27	NP
406	KN	ɛrvice Stairca	DJ	0.2	0.9	0.3	NP
407	KN	ɛrvice Stairca	DJ	0.2	0.9	0.3	NP
408	KN	ɛrvice Stairca	Thr	0.06	1	0.88	NP
409	KN	ɛrvice Stairca	DJ	0.12	1.1	0.39	NP
410	KN	ɛrvice Stairca	DJ	0.12	1.1	0.4	NP
411	KN	ɛrvice Stairca	Pier	0.5	0.67	0.76	NP
412	KN	ɛrvice Stairca	Thr	0.06	1.12	1.15	NP
413	KN	rivate Passaç	Pier	0.5	0.68	0.76	NP
414	KN	rivate Passaç	DJ	0.3	1.13	0.44	NP
415	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
416	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
417	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
418	KN	ıper Holl of D	Pier	0.3	1.13	0.44	NP
419	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
420	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
421	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
422	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
423	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
424	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
425	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
426	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
427	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
428	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
429	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
430	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
431	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
432	KN	ıper Holl of D	DJ	0.3	1.13	0.44	NP
433	KN	er Passage V	DJ	0.3	1.13	0.44	NP
434	KN	er Passage V	DJ	0.3	1.13	0.44	NP
435	KN	ɬled E-W Cor	DJ	0.3	1.13	0.44	NP
436	KN	ɬled E-W Cor	DJ	0.3	1.13	0.44	NP
437	KN	ıper Holl of C	Cop	1.05	0.62	0.15	NP
438	KN	ıper Holl of C	Cop	1.05	1.12	0.15	NP
439	KN	ıper Holl of C	Cop	1.05	1.25	0.15	NP
440	KN	ıper Holl of C	Cop	1.05	0.55	0.15	NP
441	KN	Grd Sc	Cop	1.08	1.12	0.17	NP
442	KN	Grd Sc	Cop	0.56	0.55	0.17	NP
443	KN	Grd Sc	Cop	0.15	0.55	0.46	NP
444	KN	Grd Sc	Cop	0.15	0.56	0.34	NP
445	KN	Grd Sc	Cop	0.15	0.4	0.22	NP
446	KN	Grd Sc	Cop	0.14	0.42	0.28	NP
447	KN	Grd Sc	Cop	0.16	0.67	0.61	NP
448	KN	Grd Sc	Cop	0.17	0.46	0.61	NP

	Site	Location	Function	Height	Length	Width	Date
449	KN	Grd Sc	Cop	0.17	0.67	0.63	NP
450	KN	Grd Sc	Cop	0.17	0.45	0.38	NP
451	KN	Grd Sc	Cop	0.17	0.65	0.38	NP
452	KN	Grd Sc	Cop	0.17	0.47	0.36	NP
453	KN	Grd Sc	Cop	0.17	0.63	0.16	NP
454	KN	Grd Sc	Cop	0.17	0.82	0.54	NP
455	KN	Grd Sc	Cop	0.16	0.98	0.55	NP
456	KN	Grd Sc	Cop	0.17	1.12	0.95	NP
457	KN	Grd Sc	Cop	0.17	1.07	0.73	NP
458	KN	Grd Sc	Cop	0.17	0.4	0.45	NP
459	KN	Grd Sc	Cop	0.17	0.4	0.61	NP
460	KN	Grd Sc	ScS	0.6	0.6	1.7	NP
461	KN	Grd Sc	ScS	0.6	1.13	0.91	NP
462	KN	Grd Sc	ScS	0.6	1.17	0.8	NP
463	KN	Grd Sc	ScS	0.12	0.5	1.76	NP
464	KN	Grd Sc	ScS	0.12	0.5	1.34	NP
465	KN	Grd Sc	ScS	0.12	0.5	0.3	NP
466	KN	Grd Sc	ScS	0.12	0.5	1.84	NP
467	KN	Grd Sc	ScS	0.12	0.5	0.22	NP
468	KN	Grd Sc	ScS	0.12	0.5	1.64	NP
469	KN	Grd Sc	ScS	0.12	0.5	1.07	NP
470	KN	Grd Sc	ScS	0.12	0.5	0.79	NP
471	KN	Grd Sc	ScS	0.12	0.5	0.49	NP
472	KN	Grd Sc	ScS	0.12	0.5	1.34	NP
473	KN	Grd Sc	ScS	0.12	0.5	0.3	NP
474	KN	Grd Sc	ScS	0.12	0.5	1.33	NP
475	KN	Grd Sc	ScS	0.12	0.5	0.28	NP
476	KN	Grd Sc	ScS	0.12	0.5	0.73	NP
477	KN	Grd Sc	ScS	0.12	0.5	1.17	NP
478	KN	Grd Sc	ScS	0.12	0.5	1.01	NP
479	KN	Grd Sc	ScS	0.12	0.5	0.92	NP
480	KN	Grd Sc	ScS	0.12	0.5	0.98	NP
481	KN	Grd Sc	ScS	0.12	0.5	0.83	NP
482	KN	Grd Sc	ScS	0.12	0.5	0.93	NP
483	KN	Grd Sc	ScS	0.12	0.5	0.82	NP
484	KN	Grd Sc	ScS	0.12	0.57	0.87	NP
485	KN	Grd Sc	ScS	0.12	0.57	0.93	NP
486	KN	Grd Sc	ScS	0.12	1.09	0.49	NP
487	KN	Grd Sc	ScS	0.12	1.17	1.07	NP
488	KN	Grd Sc	ScS	0.12	0.5	0.82	NP
489	KN	Grd Sc	ScS	0.12	0.5	0.83	NP
490	KN	Grd Sc	ScS	0.12	0.5	0.35	NP
491	KN	Grd Sc	ScS	0.12	0.5	1.2	NP
492	KN	Grd Sc	ScS	0.12	0.5	0.4	NP
493	KN	Grd Sc	ScS	0.12	0.5	1.33	NP
494	KN	Grd Sc	ScS	0.12	1.3	0.5	NP
495	KN	Grd Sc	ScS	0.12	1.24	0.55	NP
496	KN	Grd Sc	ScS	0.12	1.3	0.6	NP
497	KN	Grd Sc	ScS	0.12	0.5	1.86	NP
498	KN	Grd Sc	ScS	0.12	0.5	1.17	NP
499	KN	Grd Sc	ScS	0.12	0.5	0.66	NP
500	KN	Grd Sc	ScS	0.12	0.5	1.17	NP
501	KN	Grd Sc	ScS	0.12	0.5	0.73	NP
502	KN	Grd Sc	ScS	0.12	0.5	0.52	NP
503	KN	Grd Sc	ScS	0.12	0.5	1.32	NP
504	KN	Grd Sc	ScS	0.12	0.5	0.72	NP

	Site	Location	Function	Height	Length	Width	Date
505	KN	Grd Sc	ScS	0.12	0.5	1.22	NP
506	KN	Grd Sc	ScS	0.12	0.5	0.22	NP
507	KN	Grd Sc	ScS	0.12	0.5	1.77	NP
508	KN	Grd Sc	ScS	0.12	0.5	1.95	NP
509	KN	Grd Sc	ScS	0.12	0.5	1.54	NP
510	KN	Grd Sc	ScS	0.12	0.5	0.35	NP
511	KN	Grd Sc	ScS	0.12	0.5	1.47	NP
512	KN	Grd Sc	ScS	0.12	0.5	0.45	NP
513	KN	Grd Sc	ScS	0.12	0.5	0.54	NP
514	KN	Grd Sc	ScS	0.12	0.5	0.95	NP
515	KN	Grd Sc	ScS	0.12	0.5	0.35	NP
516	KN	Grd Sc	ScS	0.12	0.5	1.88	NP
517	KN	Grd Sc	ScS	0.12	0.5	1.98	NP
518	KN	Grd Sc	ScS	1.05	0.17	1.07	NP
519	KN	Grd Sc	Cop	0.38	0.17	0.64	NP
520	KN	Grd Sc	Cop	0.5	0.17	0.41	NP
521	KN	Grd Sc	Cop	0.66	0.17	0.52	NP
522	KN	Grd Sc	Cop	0.43	0.17	0.31	NP
523	KN	Grd Sc	Pier	1.1	0.92	0.98	NP
524	KN	Grd Sc	Cop	0.17	1.12	1.56	NP
525	KN	Grd Sc	Cop	0.17	1.12	0.7	NP
526	KN	Grd Sc	Cop	0.17	1.12	0.78	NP
527	KN	Grd Sc	Cop	0.17	1.12	0.68	NP
528	KN	Grd Sc	Cop	0.17	1.12	0.6	NP
529	KN	Grd Sc	Cop	0.17	1.1	1	NP
530	KN	Grd Sc	Cop	0.17	0.86	0.94	NP
531	KN	Grd Sc	Cop	0.12	0.33	0.97	NP
532	KN	Grd Sc	Cop	0.14	0.11	0.58	NP
533	KN	Grd Sc	Cop	0.14	0.1	0.55	NP
534	KN	Grd Sc	ScS	0.12	0.5	1.65	NP
535	KN	Grd Sc	ScS	0.12	0.5	1.67	NP
536	KN	Grd Sc	ScS	0.12	0.5	1.73	NP
537	KN	Grd Sc	ScS	0.12	0.5	1.6	NP
538	KN	Grd Sc	ScS	0.12	0.5	1.63	NP
539	KN	Grd Sc	ScS	0.12	0.5	1.74	NP
540	KN	Grd Sc	ScS	0.12	0.5	1.84	NP
541	KN	Grd Sc	ScS	0.12	0.5	1.8	NP
542	KN	Grd Sc	ScS	0.12	0.5	1.8	NP
543	KN	Grd Sc	ScS	0.12	0.5	1.7	NP
544	KN	Grd Sc	ScS	0.12	0.5	1.67	NP
545	KN	Grd Sc	ScS	0.12	1.68	0.5	NP
546	KN	Grd Sc	ScS	0.12	1.23	0.82	NP
547	KN	Grd Sc	ScS	0.12	1.23	0.86	NP
548	KN	Grd Sc	ScS	0.12	1.78	0.58	NP
549	KN	Grd Sc	ScS	0.12	1.78	0.58	NP
550	KN	Grd Sc	ScS	0.12	1.78	0.5	NP
551	KN	Grd Sc	ScS	0.12	0.64	0.94	NP
552	KN	Grd Sc	ScS	0.12	0.73	0.98	NP
553	KN	Grd Sc	ScS	0.12	1.37	0.82	NP
554	KN	Grd Sc	ScS	0.12	1.92	0.5	NP
555	KN	Grd Sc	ScS	0.12	1.92	0.5	NP
556	KN	Grd Sc	ScS	0.12	1.92	0.5	NP
557	KN	Grd Sc	ScS	0.12	1.92	0.5	NP
558	KN	Grd Sc	ScS	0.12	1.92	0.5	NP
559	KN	Grd Sc	ScS	0.12	1.92	0.5	NP
560	KN	Grd Sc	ScS	0.12	0.69	0.5	NP

	Site	Location	Function	Height	Length	Width	Date
561	KN	Grd Sc	ScS	0.12	1.2	0.5	NP
562	KN	Grd Sc	ScS	0.12	0.8	0.5	NP
563	KN	Grd Sc	ScS	0.12	1.11	0.5	NP
564	KN	Grd Sc	ScS	0.12	0.75	0.5	NP
565	KN	Grd Sc	ScS	0.12	1.14	0.5	NP
566	KN	Grd Sc	ScS	0.12	1.8	0.5	NP
567	KN	Grd Sc	ScS	0.12	1.8	0.5	NP
568	KN	Grd Sc	ScS	0.12	1.8	0.5	NP
569	KN	Grd Sc	Pier	1	1.04	1.03	NP
570	KN	Grd Sc-top	Pier	0.95	0.98	1	NP
571	KN	Grd Sc-top	AS	1.1	0.92	1.1	NP
572	KN	Hall of Coll	FS	0.37	1.01	0.05	NP
573	KN	Hall of Coll	FS	1.28	1.01	0.05	NP
574	KN	Hall of Coll	FS	1.2	1.3	0.05	NP
575	KN	Hall of Coll	FS	0.51	1.3	0.05	NP
576	KN	Hall of Coll	FS	0.52	1.3	0.05	NP
577	KN	Hall of Coll	FS	1.17	1.3	0.05	NP
578	KN	Hall of Coll	FS	1.2	1.3	0.05	NP
579	KN	Hall of Coll	FS	0.5	1.3	0.07	NP
580	KN	Hall of Coll	FS	0.4	1.21	0.07	NP
581	KN	Hall of Coll	FS	1.28	1.21	0.07	NP
582	KN	Hall of Coll	FS	1.3	0.97	0.07	NP
583	KN	Hall of Coll	FS	0.41	0.97	0.07	NP
584	KN	Hall of Coll	FS	0.42	0.94	0.07	NP
585	KN	Hall of Coll	FS	1.28	0.94	0.07	NP
586	KN	Hall of Coll	FS	1.27	0.9	0.07	NP
587	KN	Hall of Coll	FS	0.43	0.9	0.07	NP
588	KN	Hall of Coll	FS	0.7	0.91	0.07	NP
589	KN	Hall of Coll	FS	2.01	0.91	0.07	NP
590	KN	Hall of Coll	FS	0.84	0.92	0.07	NP
591	KN	Hall of Coll	FS	0.84	0.98	0.07	NP
592	KN	Hall of Coll	FS	1.98	0.97	0.07	NP
593	KN	Hall of Coll	FS	0.7	0.97	0.07	NP
594	KN	Hall of Coll	FS	2.03	0.94	0.07	NP
595	KN	Hall of Coll	FS	1.52	0.98	0.07	NP
596	KN	Hall of Coll	FS	0.78	0.91	0.07	NP
597	KN	Hall of Coll	FS	2.01	0.91	0.07	NP
598	KN	Hall of Coll	FS	0.75	0.91	0.07	NP
599	KN	Hall of Coll	FS	0.7	0.84	0.07	NP
600	KN	Hall of Coll	FS	2.04	0.84	0.07	NP
601	KN	Hall of Coll	FS	0.84	0.84	0.07	NP
602	KN	Hall of Coll	FS	1.41	0.84	0.07	NP
603	KN	Hall of Coll	FS	1.42	0.85	0.07	NP
604	KN	Hall of Coll	FS	0.72	0.9	0.07	NP
605	KN	Hall of Coll	FS	1.18	0.93	0.07	NP
606	KN	Hall of Coll	FS	2.12	0.9	0.07	NP
607	KN	Hall of Coll	FS	1.01	0.33	0.28	NP
608	KN	Hall of Coll	DJ	0.33	1.01	0.28	NP
609	KN	Hall of Coll	DJ	0.32	1	0.3	NP
610	KN	Hall of Coll	AS	DR	DR	DR	OP
611	KN	Hall of Coll	AS	DR	DR	DR	OP
612	KN	Hall of Coll	AS	DR	DR	DR	OP
613	KN	Hall of Coll	AS	0.5	0.5	0.62	OP
614	KN	Hall of Coll	Thr	1.1	1.05	0.06	NP
615	KN	Hall of Coll	WR	1.98	0.63	0.025	
616	KN	Hall of Coll	WR	2	1.17	0.025	

	Site	Location	Function	Height	Length	Width	Date
617	KN	Hall of Coll	WR	1.94	1.55	0.025	
618	KN	Hall of Coll	WR	1.94	1.56	0.025	
619	KN	Hall of Coll	WR	1.94	1.64	0.025	
620	KN	Hall of Coll	WR	1.95	1.5	0.025	
621	KN	Hall of Coll	Pier	0.66	1.01	0.025	
622	KN	Hall of Coll	WR	1.85	1.4	0.025	
623	KN	Hall of Coll	WR	0.89	1.4	0.025	
624	KN	Hall of Coll	WR	0.95	1.41	0.025	
625	KN	Hall of Coll	WR	0.83	1.41	0.025	
626	KN	Hall of Coll	WR	69	1.4	0.025	
627	KN	Hall of Coll	WR	0.66	1	0.025	
628	KN	Corr 87	Thr	1.06	1.26	0.06	?
629	KN	Corr 87	DJ	0.3	1.11	0.32	
630	KN	Corr 87	DJ	0.3	1.11	0.32	
631	KN	E-W Corr	FS	1.15	1.2	0.05	
632	KN	E-W Corr	FS	0.43	1.2	0.05	
633	KN	E-W Corr	FS	0.97	1.06	0.05	
634	KN	E-W Corr	FS	0.58	1.06	0.05	
635	KN	E-W Corr	FS	0.2	1	0.05	
636	KN	E-W Corr	FS	1.32	1	0.05	
637	KN	E-W Corr	FS	1.42	1.05	0.05	
638	KN	E-W Corr	FS	0.1	0.67	0.05	
639	KN	E-W Corr	FS	0.23	1.33	0.05	
640	KN	E-W Corr	FS	1.2	1.36	0.05	
641	KN	E-W Corr	FS	1.44	0.73	0.05	
642	KN	Corr 87	WR	0.12	1.27	0.04	
643	KN	Corr 87	WR	0.42	1.55	0.04	
644	KN	Corr 87	WR	0.28	1.52	0.03	
645	KN	Corr 87	WR	0.65	0.82	0.06	
646	KN	Corr 87	WR	0.25	0.58	0.07	
647	KN	Corr 87	WR	0.65	0.8	0.06	
648	KN	Corr 87	AS	0.46	0.55	1.03	
649	KN	Corr 87	AS	0.46	1.23	1.03	
650	KN	Corr 87	AS	46	1.2	1.03	
651	KN	Corr 87	WR	0.9	1.07	0.06	
652	KN	light well	AS	0.55	1.05	1.3	
653	KN	H of DAx	DJ	0.12	1.12	0.33	
654	KN	H of DAx	Thr	1.13	1.24	0.05	
655	KN	H of DAx	DJ	0.12	1.12	0.33	
656	KN	H of DAx	FS	1.06	1.43	0.05	
657	KN	H of DAx	FS	1.09	1.23	0.05	
658	KN	H of DAx	FS	1.12	0.93	0.05	
659	KN	H of DAx	FS	1.09	0.98	0.05	
660	KN	H of DAx	FS	1.01	1.03	0.05	
661	KN	H of DAx	FS	1.06	1.02	0.05	
662	KN	H of DAx	FS	1.2	1.1	0.05	
663	KN	H of DAx	FS	1.2	1.1	0.05	
664	KN	H of DAx	FS	1.16	1.1	0.05	
665	KN	H of DAx	FS	1.21	1.1	0.05	
666	KN	H of DAx	FS	1.1	0.69	0.05	
667	KN	H of DAx	FS	1.1	1.61	0.05	
668	KN	H of DAx	FS	1.1	1.23	0.05	
669	KN	H of DAx	FS	1.05	0.9	0.05	
670	KN	H of DAx	FS	1.11	0.95	0.05	
671	KN	H of DAx	FS	1.12	1.2	0.05	
672	KN	H of DAx	FS	1.1	0.97	0.05	

	Site	Location	Function	Height	Length	Width	Date
673	KN	H of DAx	FS	1.08	1	0.05	
674	KN	H of DAx	FS	1.1	1.22	0.05	
675	KN	H of DAx	FS	1.1	1.22	0.05	
676	KN	H of DAx	FS	0.83	0.85	0.05	
677	KN	H of DAx	FS	0.85	1.61	0.05	
678	KN	H of DAx	FS	1.54	0.92	0.05	
679	KN	H of DAx	FS	0.61	0.94	0.05	
680	KN	H of DAx	FS	0.77	0.9	0.05	
681	KN	H of DAx	FS	0.75	0.9	0.05	
682	KN	H of DAx	FS	0.95	0.91	0.05	
683	KN	H of DAx	FS	1	0.89	0.05	
684	KN	H of DAx	FS	1.07	0.91	0.05	
685	KN	H of DAx	FS	0.75	0.91	0.05	
686	KN	H of DAx	FS	0.72	0.84	0.05	
687	KN	H of DAx	FS	1.17	0.92	0.05	
688	KN	H of DAx	FS	1.4	0.94	0.05	
689	KN	H of DAx	FS	0.93	0.92	0.05	
690	KN	H of DAx	FS	0.82	0.95	0.05	
691	KN	H of DAx	FS	1.52	0.96	0.05	
692	KN	H of DAx	FS	1.53	1.02	0.05	
693	KN	H of DAx	FS	1.54	1.01	0.05	
694	KN	H of DAx	FS	1.53	0.9	0.05	
695	KN	H of DAx	CB	0.1		0.65	
696	KN	H of DAx	CB	0.1		0.65	
697	KN	H of DAx	DJ	0.23	0.5	0.37	
698	KN	H of DAx	WR	1.06	1.25	0.06	
699	KN	H of DAx	WR	0.99	1.14	0.06	
700	KN	H of DAx	WR	0.23	1.13	0.06	
701	KN	H of DAx	WR	0.27	1.23	0.06	
702	KN	H of DAx	WR	0.18	1.25	0.06	
703	KN	H of DAx	DJ	0.34	1.2	0.4	
704	KN	H of DAx	DJ	0.34	1.2	0.4	
705	KN	H of DAx	DJ	0.34	1.2	0.4	
706	KN	H of DAx	DJ	0.34	1.2	0.4	
707	KN	H of DAx	DJ	0.34	1.2	0.43	
708	KN	H of DAx	DJ	0.34	1.11	0.4	
709	KN	H of DAx	DJ	0.34	1.11	0.4	
710	KN	H of DAx	AS	0.6	1.07	1.05	
711	KN	H of DAx	Thr	1.13	1.22	0.03	
712	KN	H of DAx	Thr	1.47	1.2	0.03	
713	KN	H of DAx	Thr	1.47	1.2	0.03	
714	KN	H of DAx	Thr	1.52	1.2	0.03	
715	KN	H of DAx	Thr	0.7	1.2	0.05	
716	KN	H of DAx	Thr	0.73	1.2	0.05	
717	KN	H of DAx	FS	1.56	1.05	0.05	
718	KN	H of DAx	FS	1.34	1.14	0.05	
719	KN	H of DAx	FS	1.18	1.08	0.05	
720	KN	H of DAx	FS	1.38	1.04	0.05	
721	KN	H of DAx	FS	1.3	1.1	0.05	
722	KN	H of DAx	FS	1.11	1.13	0.05	
723	KN	H of DAx	FS	1.86	1.09	0.05	
724	KN	H of DAx	FS	1.25	1.11	0.05	
725	KN	H of DAx	FS	1.33	1.08	0.05	
726	KN	H of DAx	FS	0.27	1.1	0.05	
727	KN	H of DAx	FS	1.56	1.1	0.05	
728	KN	H of DAx	FS	1.15	1.08	0.05	

	Site	Location	Function	Height	Length	Width	Date
729	KN	H of DAx	FS	1.2	1.12	0.05	
730	KN	H of DAx	FS	0.35	1.14	0.05	
731	KN	H of DAx	FS	1.13	1.13	0.05	
732	KN	H of DAx	FS	1.09	0.77	0.05	
733	KN	H of DAx	FS	1.12	0.92	0.05	
734	KN	H of DAx	FS	1.12	0.82	0.05	
735	KN	H of DAx	FS	0.76	0.85	0.05	
735a	KN	H of DAx	FS	1.14	1.38	0.05	
736	KN	H of DAx	FS	0.72	1.31	0.05	
737	KN	H of DAx	FS	0.88	0.76	0.05	
738	KN	H of DAx	FS	0.137	0.82	0.05	
739	KN	H of DAx	FS	1.4	0.91	0.05	
740	KN	H of DAx	FS	1.17	0.91	0.05	
741	KN	H of DAx	FS	1.35	0.82	0.05	
742	KN	H of DAx	FS	1.33	0.88	0.05	
743	KN	H of DAx	FS	1.36	0.93	0.05	
744	KN	H of DAx	FS	1.35	0.92	0.05	
745	KN	H of DAx	FS	0.88	0.87	0.05	
746	KN	H of DAx	FS	0.65	0.89	0.05	
747	KN	H of DAx	FS	1.39	0.96	0.05	
748	KN	H of DAx	FS	1.39	1.02	0.05	
749	KN	H of DAx	FS	1.34	1.01	0.05	
750	KN	H of DAx	FS	1.33	0.97	0.05	
751	KN	H of DAx	DJ	0.3	1.2	0.5	
752	KN	H of DAx	DJ	0.3	1.2	0.4	
753	KN	H of DAx	DJ	0.3	1.2	0.4	
754	KN	H of DAx	DJ	0.3	1.2	0.4	
755	KN	H of DAx	DJ	0.3	1.2	0.4	
756	KN	H of DAx	DJ	0.3	1.12	0.4	
757	KN	H of DAx	DJ	0.3	1.12	0.4	
758	KN	H of DAx	DJ	0.3	1.12	0.4	
759	KN	H of DAx	DJ	0.3	1.12	0.4	
760	KN	H of DAx	Thr	1.24	1.45	0.05	
761	KN	H of DAx	Thr	1.2	1.44	0.05	
762	KN	H of DAx	Thr	1.2	1.47	0.05	
763	KN	H of DAx	Thr	1.24	1.48	0.05	
764	KN	H of DAx	Thr	1.12	1.3	0.05	
765	KN	H of DAx	Thr	1.12	1.28	0.05	
766	KN	H of DAx	Thr	1.16	1.28	0.05	
767	KN	H of DAx	WR	1.98	1.13	0.045	
768	KN	H of DAx	WR	1.98	1.04	0.045	
769	KN	H of DAx	WR	1.98	1.04	0.045	
770	KN	H of DAx	WR	1.98	1.02	0.045	
771	KN	H of DAx	WR	1.98	1.13	0.045	
772	KN	Corr 103	FS	1.15	1.16	0.05	
773	KN	Corr 103	FS	0.82	1.16	0.05	
774	KN	Corr 103	FS	0.82	1.16	0.05	
775	KN	Corr 103	FS	0.62	1.18	0.05	
776	KN	Corr 103	FS	0.62	1.18	0.05	
777	KN	Corr 103	FS	0.62	1.18	0.05	
778	KN	Corr 103	FS	0.7	1.16	0.05	
779	KN	Corr 103	FS	0.58	1.14	0.05	
780	KN	Corr 103	FS	0.56	0.25	0.05	
781	KN	Corr 103	FS	1.32	0.88	0.05	
782	KN	Corr 103	Thr	1.02	1.07	0.05	
783	KN	Corr 103	DJ	0.3	1.08	0.3	

	Site	Location	Function	Height	Length	Width	Date
840	KN	Q M	Thr	1.11	1.03	0.05	
841	KN	QM Bth	Thr	0.9	0.96	0.05	
842	KN	QM Bth	FS	0.76	1.08	0.05	
843	KN	QM Bth	FS	0.75	1.06	0.05	
844	KN	QM Bth	FS	0.87	1.76	0.05	
845	KN	QM Bth	FS	1.12	1.77	0.05	
846	KN	QM Bth	FS	0.61	1.19	0.05	
847	KN	QM Bth	FS	1.01	1.11	0.05	
848	KN	QM Bth	FS	0.42	1.11	0.05	
849	KN	QM Bth	FS	0.96	1.12	0.05	
850	KN	QM Bth	Cop	0.12	1.54	0.74	
851	KN	QM Bth	Pier	0.54	0.65	0.67	
852	KN	QM Bth	WR	0.55	0.87	0.03	
853	KN	QM Bth	WR	0.74	2.5	0.03	
854	KN	QM Bth	WR	0.76	0.24	0.03	
855	KN	QM Bth	WR	2	0.27	0.03	
856	KN	QM Bth	WR	2	1.08	0.03	
857	KN	QM Bth	WR	2	1.04	0.03	
858	KN	QM Bth	WR	2	0.86	0.03	
859	KN	QM Bth	WR	1.46	1.09	0.03	
860	KN	QM Bth	WR	0.95	1.08	0.03	
861	KN	QM Bth	WR	2	1.05	0.03	
862	KN	QM Bth	WR	2	1	0.03	
863	KN	QM Bth	WR	2	1.05	0.03	
864	KN	QM Bth	WR	0.76	0.32	0.03	
865	KN	QM Bth	WR	0.54	0.87	0.03	
866	KN	Corr 100	Thr	0.9	1	0.05	
867	KN	Corr 100	FS	1.28	1	0.05	
868	KN	Corr 100	FS	1.24	1	0.05	
869	KN	Corr 100	FS	1.28	0.98	0.05	
870	KN	Corr 100	FS	0.58	0.92	0.05	
871	KN	Corr 100	FS	0.61	0.94	0.05	
872	KN	Corr 100	FS	0.66	1.24	0.05	
873	KN	Corr 100	FS	1.04	0.63	0.05	
874	KN	Corr 100	FS	0.2	0.63	0.05	
875	KN	Corr 100	FS	0.84	0.6	0.05	
876	KN	Corr 100	FS	0.8	0.66	0.05	
877	KN	Corr 100	FS	1.25	0.77	0.05	
878	KN	Corr 100	FS	1.1	0.57	0.05	
879	KN	Corr 100	FS	0.83	0.64	0.05	
880	KN	Corr 100	FS	0.22	0.64	0.05	
881	KN	Corr 100	FS	0.88	0.78	0.05	
882	KN	Corr 100	FS	0.95	0.32	0.05	
883	KN	Corr 100	FS	0.91	1.16	0.05	
884	KN	Corr 100	WR	0.21	0.71	0.03	
885	KN	Corr 100	WR	0.2	0.82	0.03	
886	KN	Corr 100	Pier	0.51	0.68	0.68	
887	KN	Corr 100	WR	0.47	1.03	0.03	
888	KN	Corr 100	WR	0.97	1.29	0.03	
889	KN	Corr 100	Thr	0.97	1.02	0.05	
890	KN	Corr 100	DJ	0.3	1.03	0.3	
891	KN	Corr 100	DJ	0.3	1	0.24	
892	KN	Corr 100	DJ	0.3	1	0.24	
893	KN	WC	FS	0.98	0.85	0.1	
894	KN	WC	FS	1.04	0.64	0.1	
895	KN	WC	FS	0.36	0.56	0.1	

	Site	Location	Function	Height	Length	Width	Date
896	KN	WC	FS	0.36	0.53	0.1	
897	KN	WC	WR	0.94	1.2	0.05	
898	KN	WC	WR	1.3	1.18	0.04	
899	KN	WC	WR	0.4	1.27	0.05	
900	KN	WC	WR	0.2	1.38	0.04	
901	KN	R98	FS	1.14	1.05	0.05	
902	KN	R98	WR	1.02	0.79	0.04	
903	KN	R98	WR	0.45	1.21	0.04	
904	KN	R98	WR	0.28	1.04	0.04	
905	KN	R98	WR	1.98	0.61	0.04	
906	KN	R98	WR	0.43	1.09	0.04	
907	KN	R98	WR	0.12	0.94	0.04	
908	KN	R98	DJ	0.3	1	0.32	
909	KN	R98	DJ	0.3	1	0.24	
910	KN	R98	Thr	1.03	0.8	0.05	
911	KN	R98	DJ	0.3	1	0.29	
912	KN	R98	Thr	1.04	1	0.05	
913	KN	Kor. Of R98	DJ	0.3	1.08	0.35	
914	KN	R98	DJ	0.38	1.05	1.05	
915	KN	R98	FS	0.55	0.51	0.05	
916	KN	R98	FS	0.84	0.6	0.05	
917	KN	R98	FS	0.84	0.72	0.05	
918	KN	R98	WP	0.38	1.15	1.01	
919	KN	R98	DJ	0.3	1.03	0.28	
920	KN	R98	WP	0.11	1.16	0.55	
921	KN	R98	WP	0.13	1.01	0.61	
922	KN	R98	Thr	0.95	1.1	0.05	
923	KN	SC 104	DJ	0.3	1.03	0.53	
924	KN	SC 104	FS	1.07	0.37	0.37	
925	KN	SC 104	ScS	0.12	0.95	0.5	
926	KN	SC 104	ScS	0.12	0.95	0.5	
927	KN	SC 104	ScS	0.12	0.95	0.5	
928	KN	SC 104	ScS	0.12	0.95	0.5	
929	KN	SC 104	ScS	0.12	0.95	0.5	
930	KN	SC 104	ScS	0.12	0.95	0.5	
931	KN	SC 104	ScS	0.12	0.93	0.5	
932	KN	SC 104	ScS	0.12	0.93	0.5	
933	KN	SC 104	ScS	0.12	0.93	0.5	
934	KN	SC 104	ScS	0.12	0.92	0.5	
935	KN	SC 104	ScS	0.12	0.92	0.5	
936	KN	SC 104	ScS	0.12	0.91	0.5	
937	KN	SC 104	ScS	0.12	0.9	0.5	
938	KN	SC 104	ScS	0.12	0.9	0.5	
939	KN	SC 104	ScL	0.12	0.9	0.5	
940	KN	QM, Lt WI	ScL	0.12	0.9	0.44	
941	KN	QM, Lt WI	ScL	0.12	0.9	1.28	
942	KN	QM, Lt WI	Pier	0.8	0.59	0.66	
943	KN	QM, Lt WI	FS(all flr)	1.8	5.8	0.05	
944	KN	QM, Lt WI	FS(all flr)	0	0	0	
945	KN	QM, Lt WI	FS(all flr)	0	0	0	
946	KN	QM, Lt WI	Thr	1.1	0.104	0.05	
947	KN	QM, Lt WI	DJ	1.1	1.1	0.3	
948	KN	QM, Lt WI	DJ	1.1	1.1	0.3	
949	KN	QM, Lt WI	WR	0.15	0.58	0.4	
950	KN	QM, Lt WI	WR	0.15	0.1	0.4	
951	KN	QM, Lt WI	WR	0.55	0.73	0.3	

	Site	Location	Function	Height	Length	Width	Date
1008	KN	W-E Cor	DJ	0.33	1.22	0.3	
1009	KN	W-E Cor	DJ	0.33	1.22	0.3	
1010	KN	R 85	Pier	0.74	1.37	1	
1011	KN	R 85	WR	0.65	1.1	0.04	
1012	KN	R 85	WR	0.71	0.93	0.04	
1013	KN	R 85	WR	0.5	1.18	0.04	
1014	KN	R 85	WR	0.38	0.38	0.04	
1015	KN	R 85	Pier	0.92	0.78	0.96	
1016	KN	R 85	Cop	1.56	1.02	0.16	
1017	KN	R 85	Cop	0.18	1.04	1.02	
1018	KN	Cor 82	Pier	0.74	0.92	0.9	
1019	KN	Cor 82	DJ	0.13	1.07	0.3	
1020	KN	Cor 82	DJ	0.2	1.07	0.3	
1021	KN	School R	Gourna	0,63?	?	0.39	
1022	KN	School R	Gourna	0.28	polygon	,24/,12	
1023	KN	School R	DJ	0.07	0.49	0.16	
1024	KN	School R	DJ	0.1	0.47	0.37	
1025	KN	School R	DJ	0.15	0.53	0.47	
1026	KN	School R	DJ	0.06	0.68	0.27	
1027	KN	School R	AS	0.4	0.81	0.77	
1028	KN	School R	AS	0.2	0.82	0.53	
1029	KN	R 84	FS	1.05	0.62	0.05	
1030	KN	R 84	FS	1.5	0.53	0.05	
1031	KN	R 84	FS	1.28	0.55	0.05	
1032	KN	School R	DJ	0.3	0.7	0.44	
1033	KN	School R	DJ	0.3	0.7	0.21	
1034	KN	School R	DJ	0.3	0.7	0.29	
1035	KN	N of EW cor	AS	0.4	1.05	0.85	OP?
1036	KN	N of EW cor	AS	0.46	1.15	1.15	OP?
1037	KN	N of EW cor	AS	0.65	1.12	1.13	OP?
1038	KN	N of EW cor	DJ	0.52	0.93	0.35	
1039	KN	N of EW cor	AS	0.53	0.92	0.9	OP?
1040	KN	N of EW cor	AS	0.7	0.79	0.75	OP?
1041	KN	N of EW cor	AS	0.7	1.05	0.93	OP?
1042	KN	N of EW cor	AS	0.8	1.45	1.56	OP?
1043	KN	N of EW cor	AS	0.6	0.7	0.84	OP?
1044	KN	N of EW cor	AS	0.33	0.56	0.43	OP?
1045	KN	N of EW cor	AS	0.44	0.96	1.15	OP?
1046	KN	N of EW cor	?	0.45	0.95	0.44	OP?
1047	KN	N of EW cor	?	0.35	1.1	0.31	OP?
1048	KN	R Mag 77	FS	0.77	1.33	0.05	
1049	KN	R Mag 77	FS	0.78	1.28	0.06	
1050	KN	R Mag 77	FS	0.9	1.01	0.05	
1051	KN	R Mag 77	FS	0.8	1.65	0.05	
1052	KN	R Mag 77	FS	0.83	1.23	0.05	
1053	KN	R Mag 77	FS	0.66	0.77	0.05	
1054	KN	R Mag 77	FS	1.2	0.79	0.06	
1055	KN	R Mag 77	FS	0.6	0.63	0.12	
1056	KN	R Mag 77	FS	0.6	0.25	0.06	
1057	KN	R Mag 77	FS	0.76	1.21	0.06	
1058	KN	R Mag 77	FS	0.1	1.9	0.06	
1059	KN	R Mag 77	FS	0.77	1.15	0.06	
1060	KN	R Mag 77	FS	0.8	1.19	0.06	
1061	KN	R Mag 77	FS	0.83	0.67	0.06	
1062	KN	R Mag 77	FS	0.7	1.89	0.06	
1063	KN	R Mag 77	FS	1.04	1.46	0.06	

	Site	Location	Function	Height	Length	Width	Date
1120	KN	Area 73	AS	0.46	1.08	0.76	OP?
1121	KN	Area 73	DJ?	0.25	0.77	0.4	OP?
1122	KN	Area 73	DJ	0.38	0.9	0.35	OP?
1123	KN	Area 73	DJ	0.27	0.84	0.43	OP?
1124	KN	Area 74	AS	0.75	1.52	0.68	OP
1125	KN	Veranda	AS	0.5	1.4	0.92	OP
1126	KN	Veranda	AS	0.6	1.46	1.16	OP
1127	KN	Veranda	AS	0.55	1.2	1.52	OP
1128	KN	Veranda	DJ?	0.45	1.45	0.45	OP
1129	KN	Veranda	AS	1.2	1.2	0.99	OP
1130	KN	Veranda	AS	0.3	1.27	0.4	OP?
1131	KN	Veranda	AS	0.4	0.93	0.74	OP?
1132	KN	E. of Area 74	AS	0.28	0.79	0.55	
1133	KN	E. of Area 74	AS	0.64	0.52	1.16	
1134	KN	N. of Area 74	AS	0.35	0.74	0.52	
1135	KN	N. of Area 74	AS	0.35	0.5	0.6	
1136	KN	Area 71	AS	0.47	1.03	0.74	
1137	KN	Area 71	AS	0.26	0.6	0.37	OP?
1138	KN	Area 71	AS	0.68	0.88	0.78	OP?
1139	KN	Area 71	?	0.55	0.66	0.15	
1140	KN	Area 71	GP	0.25	1.45	0.45	
1141	KN	Area 71	AS	0.28	0.16	0.62	
1142	KN	Area 71	GP	0.28	0.49	0.53	
1143	KN	Area 71	?	0.35	0.83	0.26	
1144	KN	Area 71	GP	0.65	1.52	0.5	
1145	KN	Area 71	?	0.24	1.36	0.53	
1146	KN	Area 71	?	0.18	0.8	0.63	
1147	KN	Area 71	AS	0.2	0.71	0.52	
1148	KN	Area 71	GP	0.33	1.36	0.5	
1149	KN	Area 71	GP	0.3	1.72	0.6	
1150	KN	N. Mag	?	0.58	0.5	1.05	OP?
1151	KN	Area 71	?	0.56	0.43	1.24	
1152	KN	Area 71	AS	0.41	0.8	0.4	
1153	KN	Area 71	AS	0.45	0.45	0.36	
1154	KN	Area 71	AS	0.41	0.76	0.52	
1155	KN	Area 71	AS	0.39	1.08	0.8	
1156	KN	North Wing	ScS	0.12	1.13	0.3	NP?
1157	KN	North Wing	AS	0.35	0.52	0.35	OP?
1158	KN	North Wing	AS	0.5	1.05	0.82	OP?
1159	KN	North Wing	AS	0.32	0.96	0.82	OP?
1160	KN	North Wing	AS	0.55	1.7	0.66	OP?
1161	KN	Area 61	AS	0.2	0.38	0.31	OP?
1162	KN	Area 61	AS	0.42	1.47	x	OP?
1163	KN	Area 61	AS	0.2	0.56	0.35	OP?
1164	KN	Area 61	AS	0.15	0.56	0.54	OP?
1165	KN	Area 61	AS	0.43	0.51	0,35?	OP?
1166	KN	Area 61	AS	0.52	1.7	0.72	OP?
1167	KN	Area 61	AS	0.56	0.97	0.76	OP?
1168	KN	Area 61	AS	0.31	1.4	0.56	OP?
1169	KN	Area 61	AS	0.7	0.37	0.42	OP?
1170	KN	N Pill Hall	?	0.15	0.91	0.55	OP?
1171	KN	N Entrance	?	0.14	0.85	0.6	OP?
1172	KN	N Entrance	DJ	0.18	1.13	0.33	OP?
1173	KN	N Entrance	DJ?	0.15	0.98	0.4	OP?
1174	KN	N Entrance	?	0.05	0.35	0.38	OP?
1175	KN	N Entrance	?	0.12	0.5	0.35	OP?

	Site	Location	Function	Height	Length	Width	Date
1176	KN	N Entrance	?	0.13	1.19	0.54	OP?
1177	KN	N Entrance	FS	1.1	1.34	0.06	OP?
1178	KN	N Entrance	ASf	0.74	0.8	0.48	OP?
1179	KN	N Entrance	DJ	0.41	0.86	0.3	OP?
1180	KN	Area 67	AS	0.4	1.05	0.57	OP?
1181	KN	Area 67	AS	0.47	0.8	0.62	OP?
1182	KN	Area 67	AS	0.65	0.9	x	OP?
1183	KN	Area 67	ASf	0.65	0.4	x	OP?
1184	KN	Area 67	AS	0.78	1.08	x	OP?
1185	KN	Area 67	AS	0.82	1.19	x	OP?
1186	KN	Area 67	Pill	0.78	0.86	0.9	OP?
1187	KN	Area 67	Pill	0.74	0.9	0.94	OP?
1188	KN	Area 67	Pill	0.97	0.9	0.9	OP?
1189	KN	Area 67	Pill	0.35	1.03	1	OP?
1190	KN	Area 67	Jamp	0.2	1.44	0.6	OP?
1191	KN	Area 67	Jamp	0.11	0.4	0.15	OP?
1192	KN	Area 67	AS	0.57	1.9	1.08	OP?
1193	KN	Area 67	AS	0.62	1.9	1.12	OP?
1194	KN	Area 67	AS	0.67	1.9	1.36	OP?
1195	KN	Area 67	AS	0.25	1.35	0.58	OP?
1196	KN	Area 67	DJ	0.19	0.97	0.38	OP?
1197	KN	Area 67	DJ	0.17	0.84	0.35	OP?
1198	KN	Area 67	DJ	0.18	1.06	0.41	OP?
1199	KN	Area 67	DJ	0.17	1.05	0.49	OP?
1200	KN	Room 68	AS	0.34	0.88	0.65	OP?
1201	KN	Loose	?	0.17	0.46	0.23	OP?
1202	KN	NW Portico	DJ	0.25	1.4	0.3	NP?
1203	KN	NW Portico	DJ	0.25	1.4	0.4	NP?
1204	KN	NW Portico	DJ	0.25	1.4	0.4	NP?
1205	KN	NW Portico	DJ	0.13	1.4	0.36	NP?
1206	KN	NW Portico	DJ	0.13	1.4	0.36	NP?
1207	KN	NW Portico	?	0.21	1.4	0.47	OP?
1208	KN	Area 62	AS	0.76	1.14	1.04	OP
1209	KN	Area 62	AS	0.74	1.31	1.03	OP
1210	KN	Area 62	AS	0.64	1.07	1.03	OP
1211	KN	Area 62	AS	0.68	1.11	1.05	OP
1212	KN	Area 62	AS	0.76	1.16	1.12	OP
1213	KN	Area 62	AS	0.54	0.81	0.33	OP?
1214	KN	Area 62	AS	0.4	0.86	x	OP?
1215	KN	Area 62	AS	0.34	0.51	0.5	OP?
1216	KN	Area 62	AS	0.34	0.71	0.64	OP?
1217	KN	Area 62	DJ	0.2	1.52	0.23	NP
1218	KN	Area 62	DJ	0.2	1.55	0.2	NP
1219	KN	Area 62	DJ	0.2	1.51	0.26	NP
1220	KN	Area 62	AS	0.74	1.31	0.52	NP?
1221	KN	Area 62	AS	0.77	0.47	0.3	NP?
1222	KN	Area 62	AS	0.42	0.4	0.31	NP?
1223	KN	Area 62	AS	0.72	0.9	0.67	OP?
1224	KN	Area 62	AS	,O8	1.05	0.61	OP?
1225	KN	N LB	FS	0.74	1.09	0.06	NP
1226	KN	N LB	FS	0.41	1.08	0.06	NP
1227	KN	N LB	FS	0.4	1.08	0.06	NP
1228	KN	N LB	FS	0.47	1.09	0.06	NP
1229	KN	N LB	DJ	0.2	0.61	0.2	NP
1230	KN	N LB	DJ	0.2	0.61	0.13	NP
1231	KN	N LB	Thr	0.05	0.76	0.6	NP

	Site	Location	Function	Height	Length	Width	Date
1232	KN	N LB	ScS	0.1	1.11	0.67	NP
1233	KN	N LB	ScS	0.1	1.11	0.58	NP
1234	KN	N LB	ScS	0.1	1.11	0.58	NP
1235	KN	N LB	ScS	0.1	1.11	0.58	NP
1236	KN	N LB	ScS	0.1	1.11	0.58	NP
1237	KN	N LB	ScS	0.1	1.11	0.58	NP
1238	KN	N LB	ScS	0.1	1.11	0.58	NP
1239	KN	N LB	ScS	0.1	1.11	0.58	NP
1240	KN	N LB	ScS	0.1	1.11	0.58	NP
1241	KN	N LB	ScS	0.1	1.22	0.94	NP
1242	KN	N LB	ScS	0.1	0.98	0.5	NP
1243	KN	N LB	ScS	0.1	0.98	0.5	NP
1244	KN	N LB	ScS	0.1	0.98	0.5	NP
1245	KN	N LB	ScS	0.1	0.98	0.5	NP
1246	KN	N LB	ScS	0.1	0.9	1.06	NP
1247	KN	N LB	ScS	0.06	0.86	0.49	NP
1248	KN	N LB	FS	0.65	1.14	0.06	NP
1249	KN	N LB	FS	0.65	1.22	0.06	NP
1250	KN	N LB	FS	0.78	1.1	0.06	NP
1251	KN	N LB	FS	0.82	1.22	0.06	NP
1252	KN	N LB	FS	0.78	1.16	0.06	NP
1253	KN	N LB	FS	0.74	1.22	0.06	NP
1254	KN	N LB	WR	1.09	0.88	0.03	NP
1255	KN	N LB	WR	1.41	0.64	0.03	NP
1256	KN	N LB	WR	1.49	0.94	0.03	NP
1257	KN	N LB	WR	2	1.01	0.03	NP
1258	KN	N LB	WR	2	1.3	0.03	NP
1259	KN	N LB	WR	2	1.16	0.03	NP
1260	KN	N LB	WR	2	1.18	0.03	NP
1261	KN	N LB	WR	2	1.34	0.03	NP
1262	KN	N LB	WR	1.87	1.6	0.03	NP
1263	KN	N LB	WR	1.85	1.38	0.03	NP
1264	KN	N LB	WR	0.7	0.87	0.03	NP
1265	KN	N LB	CB	DR	0.58	0.65	NP
1266	KN	N LB	Cop	0.83	0.56	0.035	NP
1267	KN	N LB	Cop	0.1	0.56	0.035	NP
1268	KN	N LB	Cop	1.06	0.56	0.035	NP
1269	KN	N LB	CB	0.7	0.57	0.58	NP
1270	KN	N LB	CB	0.45	0.48	0.58	NP
1271	KN	N LB	CB	0.22	0.54	0.53	NP
1272	KN	N LB	WR	0.47	0.94	0.04	NP
1273	KN	N LB	WR	0.56	1.06	0.04	NP
1274	KN	N LB	WR	0.27	0.56	0.04	NP
1275	KN	N LB	WR	0.38	0.56	0.06	NP
1276	KN	N LB	WR	0.28	0.56	0.06	NP
1277	KN	N LB	WR	0.62	1.52	0.06	NP
1278	KN	N LB	WR	1.23	1.23	0.06	NP
1279	KN	N LB	WR	1.23	1.44	0.06	NP
1280	KN	N LB	WR	0.98	1.48	0.06	NP
1281	KN	N LB	WR	0.58	1.2	0.06	NP
1282	KN	R52	ScS	0.21	0.39	0.39	NP
1283	KN	R 52	AS	0.6	1.07	0.65	NP
1284	KN	R 52	AS	0.24	1.06	0.5	NP
1285	KN	R 52	AS	0.25	1.09	0.4	NP
1286	KN	R52	?	0.36	0.39	0.37	NP
1287	KN	R52	Orth	0.36	1.05	0.23	NP

	Site	Location	Function	Height	Length	Width	Date
1288	KN	R 51	ScS	0.12	0.32	0.71	NP
1289	KN	R 51	AS	0.66	0.87	0.8	NP
1290	KN	R 51	?	0.26	0.95	0.32	NP
1291	KN	R 51	FS	0.98	0.62	0.05	NP
1292	KN	R 51	FS	1.17	0.69	0.05	NP
1293	KN	R 51	FS	0.43	0.69	0.05	NP
1294	KN	R 51	FS	1.54	1.17	0.05	NP
1295	KN	R 51	FS	1.28	0.7	0.05	NP
1296	KN	R 51	FS	1.18	0.65	0.05	NP
1297	KN	R 51	FS	1.02	0.66	0.05	NP
1298	KN	R 54	AS	0.26	0.86	0.58	OP?
1299	KN	N LB	AS	0.54	1.12	0.68	OP?
1300	KN	N LB	AS	0.72	1	0.7	OP?
1301	KN	S of area 62	DJ	0.32	1.25	0.32	?
1302	KN	S of area 62	AS	0.69	1.1	0.89	OP?
1303	KN	S of area 63	AS	0.55	1.05	0.1	?
1304	KN	S of N LB	AS	0.35	0.62	1.04	?
1305	KN	S of N LB	AS	0.4	0.66	0.52	?
1306	KN	NLB	Cop	0.91	0.53	0.045	NP?
1307	KN	S of N LB	Cop	0.87	0.56	0.055	NP?
1308	KN	S of N LB	Cop	0.91	0.56	0.055	NP?
1309	KN	S of N LB	Cop	0.91	0.56	0.055	NP?
1310	KN	S of N LB	DJ	0.32	0.83	0.18	NP?
1311	KN	S of N LB	AS	0.3	0.1	0.55	OP
1312	KN	S of N LB	AS	0.4	0.6	0.42	OP
1313	KN	S of N LB	AS	0.26	0.45	0.4	OP
1314	KN	S of N LB	AS	0.44	1.11	0.4	OP
1315	KN	S of N LB	AS	0.39	1.3	0.67	OP
1316	KN	S of N LB	AS	0.66	0.44	0.7	OP
1317	KN	S of N LB	AS	0.38	0.52	x	OP
1318	KN	S of N LB	AS	0.42	0.69	0.75	OP
1319	KN	S of N LB	AS	0.5	0.77	0.63	OP
1320	KN	S of N LB	AS	0.5	1.1	0.45	OP
1321	KN	S of N LB	AS	0.62	0.69	1.05	OP
1322	KN	S of N LB	AS	0.63	1.16	x	OP
1323	KN	S of N LB	AS	0.56	0.92	x	OP
1324	KN	S of N LB	AS	0.6	1.04	x	OP
1325	KN	S of N LB	AS	0.81	0.87	x	OP
1326	KN	N of 63	AS	0.39	0.56	0.39	OP
1327	KN	N of 63	AS	0.55	5.33	0.39	OP
1328	KN	N of 63	AS	0.55	0.31	0.4	OP
1329	KN	N of 63	AS	0.62	0.65	0.52	OP
1330	KN	N of 63	AS	0.6	0.54	0.43	OP
1331	KN	N of 63	AS	0.58	0.89	0.73	OP
1332	KN	N of 63	AS	0.58	0.83	0.5	OP
1333	KN	N of 63	AS	0.6	1.4	0.73	OP
1334	KN	N Mag	FS	1.63	0.94	0.05	MOD.
1335	KN	N Mag	FS	1.63	0.9	0.05	MOD.
1336	KN	N Mag	Thr	0.92	0.77	0.05	MOD.
1337	KN	N Mag	DJ	0.3	0.78	0.24	NP?
1338	KN	N Mag	DJ	0.05	0.78	0.26	NP?
1339	KN	N Mag	AS	0.27	0.65	0.8	OP?
1340	KN	N Mag	AS	0.25	1	0.73	OP?
1341	KN	N Mag	DJ	0.21	0.9	0.2	NP?
1342	KN	N Mag	DJ	0.25	0.93	0.24	NP?
1343	KN	N Mag	AS	0.33	0.98	0.47	OP?

	Site	Location	Function	Height	Length	Width	Date
1344	KN	N Mag	AS	?	0.94	0.44	OP?
1345	KN	N Mag	DJ	0.15	1.02	0.26	NP?
1346	KN	N Mag	DJ	0.19	1.1	0.27	NP?
1347	KN	N Mag	AS	0.19	0.57	0.59	OP?
1348	KN	N Mag	AS	0.36	1.1	0.3	OP?
1349	KN	N Mag	AS	0.24	1.12	x	OP?
1350	KN	N Mag	AS	0.25	4.7	0.47	OP?
1351	KN	N Mag	AS	0.3	1.34	0.45	OP?
1352	KN	N Mag	?	0.19	0.6	0.2	OP?
1353	KN	N Mag	?	0.16	1.1	0.33	OP?
1354	KN	N Mag	AS	0.33	0.72	0.55	OP?
1355	KN	N Mag	AS	0.25	0.74	0.42	OP?
1356	KN	N Mag	DJ?	0.19	0.87	0.24	OP?
1357	KN	N Mag	DJ?	0.16	0.84	0.34	OP?
1358	KN	N Mag	DJ?	0.19	0.7	0.27	OP?
1359	KN	N Mag	DJ	0.38	1	0.32	OP?
1360	KN	N Mag	DJ	0.26	0.9	0.27	OP?
1361	KN	N Mag	FR	0.2	0.68	0.45	OP?
1362	KN	N Mag	FR	0.23	0.45	0.25	OP?
1363	KN	N Mag	FR	0.27	1.1	0.5	OP?
1364	KN	N Mag	FR	0.2	0.67	0.29	OP?
1365	KN	N Mag	FR	0.3	0.55	0.61	OP?
1366	KN	N Mag	AS	0.3	1	0.7	OP?
1367	KN	N Mag	AS	0.6	1.35	1.01	OP?
1368	KN	N Mag	AS	0.56	1.4	0.82	OP?
1369	KN	N Mag	FR	0.3	0.56	0.56	OP?
1370	KN	N Mag	DJ	0.15	0.86	0.32	NP?
1371	KN	N Mag	DJ	0.19	0.92	0.26	NP?
1372	KN	N Mag	Jamp	0.84	1.13	0.92	OP
1373	KN	N Mag	?	0.27	0.95	0.11	OP?
1374	KN	N Mag	AS	0.57	1.07	0.35	OP
1375	KN	N Mag	FR	0.7	0.6	0.2	OP?
1376	KN	N Mag	FR	0.5	0.82	0.7	OP?
1377	KN	N Mag	AS	0.38	1.17	0.55	OP?
1378	KN	N Mag	FR	0.43	0.86	0.3	OP?
1379	KN	N Mag	AS	0.53	1.4	0.75	OP?
1380	KN	N Mag	DJ	0.18	0.75	0.22	OP?
1381	KN	N Mag	ASf	0.6	0.9	0.9	OP?
1382	KN	N Mag	ASf	0.52	0.77	0.2	OP?
1383	KN	N Mag	ASf	0.26	0.8	0.27	OP?
1384	KN	N Mag	ASf	0.37	0.85	0.48	OP?
1385	KN	N Mag	ASf	0.22	0.7	0.47	OP?
1386	KN	N Mag	ASf	0.3	0.8	0.56	OP?
1387	KN	N Mag	ASf	0.62	0.44	0.28	OP?
1388	KN	N of Mag XVI	ASf	0.32	0.91	0.5	OP
1389	KN	N of Mag XVI	DJ	0.26	1.12	0.25	OP
1390	KN	N of Mag XVI	ASf	0.24	0.97	0.55	OP
1391	KN	N of Mag XVI	ASf	0.31	0.52	0.4	OP
1392	KN	N of Mag XVI	ASf	0.38	0.6	0.38	OP
1393	KN	N of Mag XVI	ASf	0.27	1.03	0.24	OP
1394	KN	N of Mag XVI	ASf	0.21	0.6	0.47	OP
1395	KN	N of Mag XVI	ASf	0.36	0.63	0.58	OP
1396	KN	N of Mag XVI	ASf	0.28	0.44	0.32	OP
1397	KN	N of Mag XVI	ASf	0.53	0.45	0.47	OP
1398	KN	N of Mag XVI	ASf	0.17	0.37	0.32	OP
1399	KN	Mg XVIII	ASf	0.47	0.44	0.63	OP

	Site	Location	Function	Height	Length	Width	Date
1456	KN	Mg XIII	FS	0.41	0.21	0.07	LM IIIA
1457	KN	Mg XIII	FS	0.5	0.6	0.07	LM IIIA
1458	KN	Mg XIII	FS	1.17	0.53	0.07	LM IIIA
1459	KN	Mg XIII	FS	1.5	0.53	0.07	LM IIIA
1460	KN	Mg XIII	FS	1.17	0.53	0.07	LM IIIA
1461	KN	Mg XIII	FS	1.21	0.51	0.07	LM IIIA
1462	KN	Mg XIII	FS	1.2	0.5	0.07	LM IIIA
1463	KN	Mg XIII	FS	1.15	0.51	0.07	LM IIIA
1464	KN	Mg XIII	FS	1.03	0.51	0.07	LM IIIA
1465	KN	Mg XIII	FS	0.31	0.52	0.07	LM IIIA
1466	KN	Mg XIII	FS	0.69	0.55	0.07	LM IIIA
1467	KN	Mg XIII	FS	1.04	0.55	0.07	LM IIIA
1468	KN	Mg XIII	FS	1.02	0.56	0.07	LM IIIA
1469	KN	Mg XIII	FS	1.08	0.56	0.07	LM IIIA
1470	KN	Mg XIII	FS	1.03	0.57	0.07	LM IIIA
1471	KN	Mg XIII	FS	0.55	0.81	0.07	LM IIIA
1472	KN	Mg XIII	FS	0.21	0.74	0.25	LM IIIA
1473	KN	Mg XIII	FS	0.26	0.66	0.25	LM IIIA
1474	KN	Mg XIII	FS	0.76	1.37	0.05	LM IIIA
1475	KN	Mg XIII	FS	0.71	1.36	0.05	LM IIIA
1476	KN	Mg XIII	FS	0.27	0.72	0.25	LM IIIA
1477	KN	Mg XIII	FS	0.27	0.66	0.25	LM IIIA
1478	KN	Mg XIII	FS	0.55	1.17	0.07	LM IIIA
1479	KN	Mg XIII	FS	1.86	0.63	0.07	LM IIIA
1480	KN	Mg XIII	DJ	0.8	0.64	0.07	NP?
1481	KN	Mg XIII	DJ	0.74	0.63	0.07	NP?
1482	KN	Mg XIII	Thr	1.02	0.63	0.07	NP?
1483	KN	Mg XIII	Thr	1.04	0.62	0.07	NP?
1484	KN	Mg XIII	DJ	1.01	0.65	0.07	NP?
1485	KN	Mg XIII	DJ	0.76	0.66	0.07	NP?
1486	KN	Mg XIII	FSsum	3.42	0.7	0.07	LM IIIA
1487	KN	Mg XIII	FS	1	0.63	0.07	LM IIIA
1488	KN	Mg XIII	FS	0.32	0.59	0.07	LM IIIA
1489	KN	Mg XIII	FS	0.98	0.58	0.07	LM IIIA
1490	KN	Mg XIII	FS	1.5	0.6	0.07	LM IIIA
1491	KN	Mg XIII	FS	0.4	0.58	0.07	LM IIIA
1492	KN	Mg XIII	FS	0.41	0.96	0.07	LM IIIA
1493	KN	Mg XIII	FS	0.88	0.95	0.07	LM IIIA
1494	KN	Mg XIII	FS	0.88	0.69	0.07	LM IIIA
1495	KN	Mg XIII	FS	0.55	0.69	0.07	LM IIIA
1496	KN	Mg XIII	FS	0.55	0.62	0.07	LM IIIA
1497	KN	Mg XIII	FS	0.22	0.84	0.07	LM IIIA
1498	KN	Mg XIII	FS	0.9	0.2	0.07	LM IIIA
1499	KN	Mg XIII	FS	0.56	0.4	0.07	LM IIIA
1500	KN	Mg XIII	FS	0.52	0.7	0.07	LM IIIA
1501	KN	Mg XIII	FS	0.65	0.36	0.07	LM IIIA
1502	KN	Mg XIII	FS	0.64	0.37	0.07	LM IIIA
1503	KN	Mg XIII	FS	0.64	0.4	0.07	LM IIIA
1504	KN	Mg XIII	FS	0.625	0.4	0.07	LM IIIA
1505	KN	Mg XIII	FS	0.62	0.37	0.07	LM IIIA
1506	KN	Mg XIII	FS	0.35	0.64	0.07	LM IIIA
1507	KN	Mg XIII	FS	0.5	1.22	0.045	LM IIIA
1508	KN	Mg XIII	FS	0.5	1.62	0.045	LM IIIA
1509	KN	Mg XIII	FS	0.5	1.6	0.045	LM IIIA
1510	KN	Mg XIII	FS	0.5	0.85	0.045	LM IIIA
1511	KN	Mg XIII	FS	0.5	1.08	0.045	LM IIIA

	Site	Location	Function	Height	Length	Width	Date
1512	KN	Mg XIII	FS	0.5	1.37	0.045	LM IIIA
1513	KN	Mg XIII	FS	0.5	1.27	0.045	LM IIIA
1514	KN	Mg XIII	FS	0.5	0.82	0.045	LM IIIA
1515	KN	Mg XIII	WR	0.5	0.8	0.045	LM IIIA
1516	KN	Mg XIII	WR	0.5	0.96	0.045	LM IIIA
1517	KN	Mg XIII	WR	0.5	1.15	0.045	LM IIIA
1518	KN	Mg XIII	WR	0.5	1.36	0.045	LM IIIA
1519	KN	Mg XIII	WR	0.5	1.4	0.045	LM IIIA
1520	KN	Mg XIII	WR				LM IIIA
1521	KN	Mg XIII	WR				LM IIIA
1522	KN	Mg XIII	WR				LM IIIA
1523	KN	Mg XIII	WR				LM IIIA
1524	KN	Mg XIII	WR				LM IIIA
1525	KN	Mg XIII	WR				LM IIIA
1526	KN	Mg XIII	WR				LM IIIA
1527	KN	Cor of Mg	Thr				LM IIIA
1528	KN	Cor of Mg	AS				LM IIIA
1529	KN	Cor of Mg	AS	0.17	0.56	0.44	OP
1530	KN	Cor of Mg	AS	0.46	0.85	0.33	OP
1531	KN	Cor of Mg	AS	0.38	0.45	0.34	OP
1532	KN	Cor of Mg	ASf	0.48	0.41	0.58	OP
1533	KN	Cor of Mg	ASf	0.25	4	0.4	OP
1534	KN	Cor of Mg	Jamp	1.03	0.69	0.6	OP
1535	KN	Cor of Mg	FR	0.7	1.12	0.1	OP
1536	KN	Cor of Mg	FR	0.74	1.12	0.1	OP
1537	KN	Cor of Mg	Jamp	1.35	0.55	0.45	OP
1538	KN	Cor of Mg	Jamp	1.35	0.55	0.94	OP
1539	KN	Cor of Mg	ASf	0.22	0.4	0.56	OP
1540	KN	Cor of Mg	ASf	0.3	0.5	0.6	OP
1541	KN	Cor of Mg	ASf	0.17	0.5	0.66	OP
1542	KN	Cor of Mg	ASf	0.2	0.55	0.55	OP
1543	KN	Cor of Mg	ASf	0.58	0.4	0.24	OP
1544	KN	Cor of Mg	ASf	0.34	0.5	0.47	OP
1545	KN	Cor of Mg	Jamp	1.12	0.53	0.63	OP
1546	KN	Cor of Mg	Jamp	1.12	0.79	1	OP
1547	KN	Cor of Mg	ASf	1.4	0.38	X	OP
1548	KN	Cor of Mg	Pier	0.98	0.58	0.54	NP?
1549	KN	Cor of Mg	Scs	0.08	1.01	0.57	NP?
1550	KN	Cor of Mg	Scs	0.14	1.01	0.25	NP?
1551	KN	Cor of Mg	Scs	0.2	1.01	0.26	NP?
1552	KN	Cor of Mg	Scs	0.16	1.01	0.43	NP?
1553	KN	Cor of Mg	Scs	0.12	1	0.33	NP?
1554	KN	Cor of Mg	Scs	0.12	1	0.36	NP?
1555	KN	Mg XII	Orth.	0.5	2	0.53	OP
1556	KN	Mg XII	WR	0.17	0.34	0.035	LM IIIA
1557	KN	Mg XII	WR	0.17	0.67	0.035	LM IIIA
1558	KN	Mg XII	FS	0.66	0.42	0.07	NP
1559	KN	Mg XII	FS	0.71	0.47	0.07	NP
1560	KN	Mg XII	FS	0.7	0.4	0.07	LM IIIA
1561	KN	Mg XII	FS	0.99	0.5	0.07	LM IIIA
1562	KN	Mg XII	FS	0.42	0.54	0.07	LM IIIA
1563	KN	Mg XII	FS	0.98	0.52	0.07	LM IIIA
1564	KN	Mg XII	FS	1.11	0.45	0.07	LM IIIA
1565	KN	Mg XII	FS	1.58	0.19	0.07	LM IIIA
1566	KN	Mg XII	FS	1.45	0.41	0.07	LM IIIA
1567	KN	Mg XII	FS	0.65	0.5	0.07	NP

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	Site	Location	Function	Height	Length	Width	Date
1568	KN	Mg XII	FS	0.63	0.5	0.07	NP
1569	KN	Mg XII	FS	0.7	0.5	0.07	NP
1570	KN	Mg XII	FS	0.66	0.5	0.07	NP
1571	KN	Mg XII	FS	0.82	0.56	0.07	LM IIIA
1572	KN	Mg XII	FS	1.01	0.6	0.07	LM IIIA
1573	KN	Mg XII	FS	0.58	0.34	0.07	LM IIIA
1574	KN	Mg XII	FS	0.48	0.23	0.07	LM IIIA
1575	KN	Mg XII	FS	0.39	0.37	0.07	LM IIIA
1576	KN	Mg XII	FS	1.92	0.62	0.07	LM IIIA
1577	KN	Mg XII	FS	0.45	0.6	0.07	LM IIIA
1578	KN	Mg XII	FS	0.41	0.57	0.07	LM IIIA
1579	KN	Mg XII	FS	0.68	0.56	0.07	LM IIIA
1580	KN	Mg XII	FS	0.93	0.5	0.07	LM IIIA
1581	KN	Mg XII	FS	0.98	0.23	0.07	LM IIIA
1582	KN	Mg XII	FS	0.85	0.33	0.07	LM IIIA
1583	KN	Mg XII	FS	0.65	1.06	0.07	LM IIIA
1584	KN	Mg XII	FS	0.66	0.86	0.07	LM IIIA
1585	KN	Mg XII	FS	0.78	0.68	0.07	LM IIIA
1586	KN	Mg XII	Thr	1.37	0.75	0.06	NP
1587	KN	Mg XII	DJ	0.18	0.76	0.25	NP
1588	KN	Mg XII	FS	1.21	0.59	0.07	LM IIIA
1589	KN	Mg XII	FS	0.55	0.59	0.07	LM IIIA
1590	KN	Mg XII	FS	1.71	0.59	0.07	LM IIIA
1591	KN	Mg XII	FS	1.67	0.6	0.07	LM IIIA
1592	KN	Mg XII	FS	0.45	0.59	0.07	LM IIIA
1593	KN	Mg XII	FS	0.42	0.59	0.07	LM IIIA
1594	KN	Mg XII	FS	1.45	0.59	0.07	LM IIIA
1595	KN	Mg XII	FS	1.01	0.59	0.07	LM IIIA
1596	KN	Mg XII	FS	0.68	0.59	0.07	LM IIIA
1597	KN	Mg XII	FS	1.08	0.59	0.07	LM IIIA
1598	KN	Mg XII	FS	0.4	0.27	0.07	LM IIIA
1599	KN	Mg XII	FS	0.53	0.28	0.07	LM IIIA
1600	KN	Mg XII	FS	0.46	0.51	0.035	LM IIIA
1601	KN	Mg XII	FS	0.55	0.51	0.035	LM IIIA
1602	KN	Mg XII	FS	0.62	0.25	0.035	LM IIIA
1603	KN	Mg XII	FS	0.53	0.35	0.035	LM IIIA
1604	KN	Mg XII	FS	0.77	0.22	0.035	LM IIIA
1605	KN	Mg XII	FS	0.77	0.37	0.035	LM IIIA
1606	KN	Mg XII	FS	0.85	0.56	0.035	LM IIIA
1607	KN	Mg XII	FS	0.97	0.43	0.035	LM IIIA
1608	KN	Mg XII	FS	1.14	0.1	0.035	LM IIIA
1609	KN	Mg XII	FS	1.22	0.6	0.035	LM IIIA
1610	KN	Mg XII	FS	0.42	0.6	0.035	LM IIIA
1611	KN	Mg XII	FS	0.45	0.57	0.035	LM IIIA
1612	KN	Mg XII	FS	0.24	0.58	0.035	LM IIIA
1613	KN	Mg XII	FS	0.44	0.55	0.035	LM IIIA
1614	KN	Mg XII	FS	0.7	0.46	0.035	LM IIIA
1615	KN	Mg XII	FS	0.48	0.48	0.035	LM IIIA
1616	KN	Mg XII	FS	0.49	0.45	0.035	LM IIIA
1617	KN	Mg XII	FS	0.5	0.53	0.035	LM IIIA
1618	KN	Mg XII	FS	0.42	0.5	0.035	LM IIIA
1619	KN	Mg XI	Orth	1.03	1.27	0.55	OP
1620	KN	Mg XI	Orth	1.09	1.92	0.45	OP
1621	KN	Mg XI	Orth	1.07	1.68	0.4	OP
1622	KN	Mg XI	Orth	0.8	1.07	0.45	OP
1623	KN	Mg X	Orth	1.13	1.16	0.4	OP

	Site	Location	Function	Height	Length	Width	Date
1624	KN	Mg X	Orth	1.1	90	0.46	OP
1625-1678	KN	Mg X	total	18.8	1.9	0.07	
	KN	Mg XII	total	14	2	0.07	
	KN	Mg IX	total	14	2	0.07	
	KN	Mg VIII	total	14	2	0.07	
	KN	Mg VII	total	14	2	0.07	
	KN	Mg VI	total	14	2	0.07	
	KN	Mg V	total	13	2.7	0.07	
	KN	Mg IV	total	13	2.7	0.07	
	KN	Mg III	total	13	2.7	0.07	
1679	KN	J13-12	Jamp	1.44	0.56	0.7	OP
1680	KN	J13-12	Jamp	1.44	0.8	0.83	OP
1681	KN	J12-11	Jamp	1.08	0.58	0.7	OP
1682	KN	J12-11	Jamp	1.08	0.78	0.73	OP
1683	KN	J11-10	Jamp	1.58	0.62	0.75	OP
1684	KN	J11-10	Jamp	1.58	0.785	0.72	OP
1685	KN	J10-9	Jamp	1.3	0.615	0.65	OP
1686	KN	J10-9	Jamp	1.3	0.79	0.57	OP
1687	KN	J9-8	Jamp	1.1	0.6	0.9	OP
1688	KN	J9-8	Jamp	1.1	0.8	0.76	OP
1689	KN	J8-7	Jamp	1.54	0.65	0.61	OP
1690	KN	J8-7	Jamp	1.54	0.815	0.66	OP
1691	KN	J7-6	Jamp	1.11	0.6	0.78	OP
1692	KN	J7-6	Jamp	1.11	0.785	0.67	OP
1693	KN	J6-5	Jamp	1.33	0.64	0.83	OP
1694	KN	J6-5	Jamp	1.33	0.76	0.7	OP
1695	KN	J5-4	Jamp	1.29	0.64	0.85	OP
1696	KN	J5-4	Jamp	1.29	0.76	0.89	OP
1697	KN	J4-3	Jamp	1.11	0.62	0.7	OP
1698	KN	J4-3	Jamp	1.11	0.78	0.57	OP
1699	KN	J3-2	Jamp	1.3	0.63	0.58	OP
1700	KN	J3-2	Jamp	1.3	0.74	0.6	OP
1701	KN	J2-1	Jamp	1.15	0.61	0.74	OP
1702	KN	J2-1	Jamp	1.15	0.74	0.72	OP
1703	KN	J1	Jamp	1.15	0.64	0.95	OP
1704	KN	1J	Jamp	1.15	0.75	0.86	OP
1705	KN	R19	AS				
1706	KN	R19	AS				
1707	KN	R19	AS				
1708	KN	R19	AS				
1709	KN	R19	AS				
1710	KN	R19	AS				
1711	KN	R19	AS				
1712	KN	R19	AS				
1713	KN	R19	AS				
1714	KN	R19	AS				
1715	KN	R19	AS				
1716	KN	R19	AS				
1717	KN	R19	AS				
1718	KN	R19	AS				
1719	KN	R19	AS				
1720	KN	R19	AS				
1721	KN	R19	AS				
1722	KN	R19	AS				
1723	KN	R19	AS				
1724	KN	R18	AS				

	Site	Location	Function	Height	Length	Width	Date
1725	KN	R18	AS				
1726	KN	SE of 22	AS	0.82	0.8	0.5	
1727	KN	R 22	ASf	0.5	0.48	0.8	
1728	KN	R 22	ASf	0.65	0.27	0.87	
1729	KN	R 22	AS	1	0.75	0.36	
1730	KN	R 23	AS	0.72	0.7	0.45	
1731	KN	R 24	AS	0.78	2.56	0.4	
1732	KN	R 24	AS	0.54	1.23	0.36	
1733	KN	R 24	AS	0.78	1.15	0.46	
1734	KN	R 24	AS	0.62	2.2	0.6	
1735	KN	R 24	Orth	0.67	0.9	0.25	
1736	KN	R 24	Orth	0.67	2.23	0.27	
1737	KN	R 24	Orth	0.64	1.74	0.24	
1738	KN	R 25	DJ	0.32	1	0.25	
1739	KN	R 25	DJ	0.17	1	0.35	
1740	KN	R 25	FS	1.01	0.63	0.05	
1741	KN	R 25	FS	1.01	0.84	0.05	
1742	KN	R 25	FS	1.01	0.94	0.05	
1743	KN	R 25	CB	0.18	0.5	0.59	
1744	KN	R 25	FS	0.42	0.36	0.05	
1745	KN	R 25	FS	0.7	0.48	0.05	
1746	KN	R 25	FS	0.5	0.45	0.05	
1747	KN	R 25	FS	0.61	0.65	0.05	
1748	KN	R 25	FS	0.59	0.52	0.05	
1749	KN	R 25	DJ	0.31	1.01	0.26	
1750	KN	R 25	DJ	0.25	1	0.27	
1751	KN	R 25	Corner	0.59	1.28	0.75	
1752	KN	R 25	DJ?	0.25	1.1	0.33	
1753	KN	R 25	DJ?	0.28	0.46	0.7	
1754	KN	R 25	AS	0.59	0.92	0.64	
1755	KN	R 27	AS	0.69	1.17	0.54	
1756	KN	R 27	AS	0.8	1.12	0.8	
1757	KN	R 27	AS	0.61	0.93	0.54	
1758	KN	R 27	AS	0.84	0.93	0.38	
1759	KN	R 27	AS	0.63	1.06	0.52	
1760	KN	R 27	AS	0.5	0.87	0.74	
1761	KN	R 27	AS	0.74	X	0.5	
1762	KN	R 27	AS	0.44	X	1.09	
1763	KN	R 27	ASf	0.54	0.6	0.9	
1764	KN	R 26	FS	1.7	0.45	0.05	
1765	KN	R 26	AS	0.42	1.18	0.34	
1766	KN	R 26	AS	0.48	0.68	1.17	
1767	KN	N of R 25	FS	0.53	0.63	0.07	
1768	KN	N of R 25	FS	0.53	0.455	0.07	
1769	KN	N of R 25	FS	0.53	0.44	0.07	
1770	KN	N of R 25	FS	0.53	0.49	0.07	
1771	KN	N of R 25	FS	0.4	0.27	0.07	
1772	KN	N of R 25	ScS	0.72	0.75	0.065	
1773	KN	N of R 25	ScS	15	0.75	0.065	
1774	KN	N of R 25	ScS	25	0.72	0.065	
1775	KN	N of R 25	ScS	0.29	1.2	0.095	
1776	KN	R 32	FS	0.77	1.24	0.06	
1777	KN	R 32	FS	0.97	1.03	0.06	
1778	KN	R 32	FS	0.61	1.03	0.06	
1779	KN	R 32	FS	0.85	1.04	0.06	
1780	KN	R 32	FS	0.7	1.05	0.06	

	Site	Location	Function	Height	Length	Width	Date
1837	KN	R 33	Cist	0.35	1.37	0.07	
1838	KN	R 33	Cist	0.35	0.53	0.07	
1839	KN	R 33	Cist	0.35	1.38	0.07	
1840	KN	R 33	Cist	0.43	1.38	0.07	
1841	KN	R 34	FS	1.2	0.2	0.05	
1842	KN	R 34	Thr	1.16	0.68	0.05	
1843	KN	R 34	DJ	0.36	0.68	0.3	
1844	KN	R 34	FS	1.85	0.82	0.05	
1845	KN	R 34	Cist	0.42	0.39	0.07	
1846	KN	R 34	Cist	0.42	0.4	0.07	
1847	KN	R 34	Cist	0.42	1.06	0.07	
1848	KN	R 34	Cist	0.42	1.06	0.07	
1849	KN	R 34	Cist	0.82	0.4	0.07	
1850	KN	Corr 28	DJ	0.1	1.01	0.2	
1851	KN	Corr 28	DJ	0.15	1.02	0.44	
1852	KN	Corr 28	FSsum	12.1	1.2	0.05	
1853	KN	Corr 28	WP	0.63	1.33	0.5	
1854	KN	Corr 28	WP	0.68	1.35	0.5	
1855	KN	Corr 28	WP	0.6	0.93	0.6	
1856	KN	Corr 28	WP	0.82	0.89	0.52	
1857	KN	Corr 28	WP	0.79	1.06	0.36	
1858	KN	Corr 28	WP	0.65	1.05	0.34	
1859	KN	Corr 28	WP	0.2	1.04	0.37	
1860	KN	Corr 28	WP	0.2	1.1	0.35	
1861	KN	R 30	DJ	0.3	1	0.25	
1862	KN	R 30	DJ	0.3	1	0.25	
1863	KN	R 30	DJ	0.3	1	0.25	
1864	KN	R 30	Thr	0.7	1.12	0.05	
1865	KN	R 30	Thr	0.7	1.12	0.05	
1866	KN	Corr 28	FSsum	5	1.4	0.05	
1867	KN	Corr 28	FS	1	1.3	0.05	
1868	KN	R 30	FSsum	5.1	3.5	0.05	
1869	KN	Bat R	DJ	0.3	1.4	0.35	
1870	KN	Bat R	DJ	0.3	1.4	0.35	
1871	KN	Bat R	WP	1.8	0.7	0.5	
1872	KN	Bat R	WP	1.8	0.7	0.5	
1873	KN	Bat R	WP	1.4	0.5	0.5	
1874	KN	Bat R	WP	1.4	0.5	0.5	
1875	KN	Bat R	WP	1.4	0.6	0.5	
1876	KN	Bat R	WP	1.4	0.6	0.5	
1877	KN	R 29	Thr	0.7	1.12	0.05	
1878	KN	R 29	DJ	0.32	0.9	0.61	
1879	KN	R 29	DJ	0.3	0.9	0.61	
1880	KN	R 29	DJ	0.3	0.6	0.3	
1881	KN	R 29	FSsum	3	2.2	0.05	
1882	KN	R 29	Pill	0.6	0.6	0.8	
1883	KN	R 29	Pill	0.6	0.6	0.8	
1884	KN	R 29	Pill	0.6	0.6	0.8	
1885	KN	R 29	Pill	0.6	0.6	0.8	
1886	KN	R 30	Pill	0.6	0.6	0.8	
1887	KN	R 30	Pill	0.6	0.6	0.8	
1888	KN	R 30	Pill	0.6	0.6	0.8	
1889	KN	R 30	Pill	0.6	0.6	0.8	
1890	KN	R 31	DJ	0.3	1	0.35	
1891	KN	R 31	DJ	0.3	1	0.35	
1892	KN	R 31	FS	1.4	4.3	0.05	

	Site	Location	Function	Height	Length	Width	Date
1893	KN	R 31	Thr	0.7	1.12	0.05	
1894	KN	R 31	Thr	0.7	1.12	0.05	
1895	KN	SC 37	CB				
1896	KN	SC 37	CB				
1897	KN	R 41	DJ	0.25	0.87	0.35	
1898	KN	R 41	DJ	0.25	0.87	0.35	
1899	KN	R 41	DJ	0.25	0.87	0.35	
1900	KN	R 41	DJ	0.25	0.87	0.35	
1901	KN	R 41	DJ	0.14	0.87	0.35	
1902	KN	R 41	Pier	0.96	0.86	0.96	
1903	KN	R 41	ScS	0.15	1.35	0.5	
1904	KN	R 41	ScS	0.15	1.2	0.37	
1905	KN	R 41	ScS	0.11	1.24	0.43	
1906	KN	R 41	ScS	0.12	0.82	0.38	
1907	KN	R 41	ScS	0.12	0.45	0.38	
1908	KN	R 41	ScS	0.1	0.71	0.38	
1909	KN	R 41	ScS	0.1	0.83	0.38	
1910	KN	R 41	ScS	0.1	0.75	0.38	
1911	KN	R 41	ScS	0.1	0.79	0.38	
1912	KN	R 41	ScS	0.1	1.05	0.38	
1913	KN	R 41	ScS	0.1	1	0.38	
1914	KN	R 41	ScS	0.1	0.74	0.38	
1915	KN	R 41	ScS	0.125	0.77	0.38	
1916	KN	R 41	ScS	0.125	1.1	0.38	
1917	KN	R 41	ScS	0.125	0.75	0.38	
1918	KN	R 41	ScS	0.125	0.65	0.38	
1919	KN	R 41	ScS	0.125	0.8	0.38	
1920	KN	R 41	ScS	0.125	0.95	0.38	
1921	KN	R 41	ScS	0.125	0.73	0.38	
1922	KN	R 41	ScS	0.125	0.45	0.38	
1923	KN	R 41	ScS	0.12	1.16	0.38	
1924	KN	R 41	ScS	0.15	1.16	0.48	
1925	KN	R 41	ScS	0.12	1.16	0.39	
1926	KN	R 41	ScS	0.12	1.16	0.5	
1927	KN	R 41	ScS	0.12	1.41	0.36	
1928	KN	R 41	ScS	0.12	1.41	0.5	
1929	KN	R 41	ScS	0.12	1.17	0.38	
1930	KN	R 41	ScS	0.12	1.17	0.52	
1931	KN	R 41	FS	1.27	1.02	0.05	
1932	KN	R 41	FS	1.15	0.74	0.05	
1933	KN	R 41	FS	0.89	0.74	0.05	
1934	KN	R 41	FS	1.22	0.85	0.05	
1935	KN	R 41	FS	1	1.07	0.05	
1936	KN	R 41	FS				
1937	KN	R 41	FS	0.92	0.66	0.05	
1938	KN	R 41	FS	0.93	0.35	0.05	
1939	KN	R 41	FS	0.8	1	0.05	
1940	KN	R 41	FS	0.95	1.05	0.05	
1941	KN	R 41	FS	0.95	0.55	0.05	
1942	KN	R 41	FS	1.07	1.12	0.05	
1943	KN	R 41	FS	0.61	1.15	0.05	
1944	KN	R 41	FS	0.61	0.58	0.05	
1945	KN	R 41	FS	0.1	0.45	0.05	
1946	KN	R 41	FS	1.03	0.295	0.05	
1947	KN	R 41	FS	1.02	0.59	0.05	
1948	KN	R 41	FS	1.02	0.755	0.05	

	Site	Location	Function	Height	Length	Width	Date
2005	KN	R 42	BS	0.3	0.6	0.03	
2006	KN	R 42	BS	0.3	0.38	0.03	
2007	KN	R 42	BS	0.3	0.6	0.03	
2008	KN	R 42	BS	0.3	0.33	0.03	
2009	KN	R 42	BS	0.89	0.42	0.09	
2010	KN	R 42	BS	1.74	0.42	0.09	
2011	KN	R 42	BS	0.3	0.33	0.03	
2012	KN	R 42	BS	0.3	83	0.03	
2013	KN	R 42	BS	0.3	0.35	0.03	
2014	KN	R 42	BS	1.5	0.39	0.095	
2015	KN	R 42	BS	1.32	0.4	0.095	
2016	KN	R 42	BS	0.6	0.4	0.095	
2017	KN	R 42	BS	0.3	0.43	x	
2018	KN	R 42	BS	0.3	1.07	x	
2019	KN	R 42	BS	0.3	0.375	x	
2020	KN	R 42	BS	0.3	0.41	x	
2021	KN	R 42	BS	0.3	1.1	x	
2022	KN	R 42	BS	0.3	0.385	x	
2023	KN	R 42	BS	0.3	1.1	x	
2024	KN	R 42	BS	0.3	0.4	x	
2025	KN	R 42	BS	0.9	0.44	0.09	
2026	KN	R 42	BS	0.89	0.43	0.09	
2027	KN	R 42	BS	1	0.42	0.09	
2028	KN	R 42	BS	0.71	0.42	0.09	
2029	KN	R 42	Balust	0.35	1.39	0.035	
2030	KN	R 42	Balust	0.35	1.38	0.035	
2031	KN	R 42	Balust	0.64	0.47	0.01	
2032	KN	R 42	Balust	1.1	0.46	0.01	
2033	KN	R 42	Balust	1.15	0.46	0.01	
2034	KN	LB 43	WR	0.78	0.38	0.095	
2035	KN	LB 43	WR	0.43	0.44	0.045	
2036	KN	LB 43	WR	0.485	0.77	0.105	
2037	KN	LB 43	Pier	0.8	0.4	0.46	
2038	KN	LB 43	WR	0.34	0.11	0.04	
2039	KN	LB 43	WR	0.63	0.54	0.04	
2040	KN	LB 43	WR	0.44	16	0.04	
2041	KN	LB 43	ScS	0.11	0.95	0.38	
2042	KN	LB 43	ScS	0.11	0.95	0.32	
2043	KN	LB 43	ScS	0.11	0.95	0.33	
2044	KN	LB 43	ScS	0.11	0.95	0.34	
2045	KN	LB 43	ScS	0.11	0.58	0.88	
2046	KN	LB 43	ScS	0.11	0.36	0.88	
2047	KN	LB 43	ScS	0.09	0.45	0.88	
2048	KN	LB 43	WR	0.43	0.29	0.04	
2049	KN	LB 43	WR	0.51	1.03	0.04	
2050	KN	LB 43	WR	0.97	1.03	0.04	
2051	KN	LB 43	WR	1.1	1.06	0.04	
2052	KN	LB 43	WR	1.23	2.06	0.04	
2053	KN	LB 43	WR	1.23	1.17	0.04	
2054	KN	LB 43	WR	1.23	2.07	0.04	
2055	KN	LB 43	WR	1.24	1.2	0.04	
2056	KN	LB 43	WR	1.24	1	0.04	
2057	KN	LB 43	WR	1.24	0.68	0.04	
2058	KN	LB 43	WR	1.23	0.79	0.03	
2059	KN	LB 43	FS	1.03	1.28	0.065	
2060	KN	LB 43	FS	1.07	0.8	0.065	

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	Site	Location	Function	Height	Length	Width	Date
2061	KN	LB 43	FS	1.25	0.97	0.065	
2062	KN	LB 43	FS	0.8	0.96	0.065	
2063	KN	LB 43	FS	1.31	0.87	0.065	
2064	KN	LB 43	FS	0.75	0.87	0.065	
2065	KN	R 42	FS	0.44	0.93	0.045	
2066	KN	R 42	FS	1.15	0.36	0.045	
2067	KN	R 42	FS	1.36	1.2	0.045	
2068	KN	R 42	FS	1.26	1.2	0.045	
2069	KN	R 42	Thr	0.96	0.93	0.045	
2070	KN	R 42	DJ	0.3	0.89	0.32	
2071	KN	R 42	DJ	0.3	0.89	0.32	
2072	KN	R 38a	Seat?	0.54	0.64	0.055	
2073	KN	R 38a	Seat?	0.53	0.32	0.05	
2074	KN	R 38a	Seat?	0.89	0.34	0.06	
2075	KN	R 38a	Seat?	0.103	0.36	0.09	
2076	KN	R 38	WR	0.91	0.68	0.03	
2077	KN	R 38	WR	1.44	1.13	0.03	
2078	KN	R 38	WR	0.82	1.23	0.03	
2079	KN	R 38	WR	0.5	0.55	0.03	
2080	KN	R 38	Cist	1.18	0.71	0.07	

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	Site	Location	Function	Height	Width	Length	Date
115	NH	Room 2a	S\ Fr				MMIII/LMI
116	NH	Room 2a	S\ Fr				MMIII/LMI
117	NH	Room 2a	S\ Fr				MMIII/LMI
118	NH	Room 2a	S\ Fr				MMIII/LMI
119	NH	Room 2a	S\ Fr				MMIII/LMI
120	NH	Room 2a	S\ Fr				MMIII/LMI
121	NH	Room 2a	S\ Fr				MMIII/LMI
122	NH	Room 2a	S\ Fr				MMIII/LMI
123	NH	Room 2a	S\ Fr				MMIII/LMI
124	NH	Room 2a	S\ Fr				MMIII/LMI
125	NH	Room 2a	S\ Fr				MMIII/LMI
126	NH	Room 2a	S\ Fr				MMIII/LMI
127	NH	Room 2a	S\ Fr				MMIII/LMI
128	NH	Room 2a	S\ Fr				MMIII/LMI
129	NH	Room 2a	S\ Fr				MMIII/LMI
130	NH	Room 2a	S\ Fr				MMIII/LMI
131	NH	Room 2a	S\ Fr				MMIII/LMI
132	NH	Room 2a	S\ Fr				MMIII/LMI
133	NH	Room 2a	S\ Fr				MMIII/LMI
134	NH	Room 2a	S\ Fr				MMIII/LMI
135	NH	Room 2a	S\ Fr				MMIII/LMI
136	NH	Room 2a	S\ Fr				MMIII/LMI
137	NH	Room 2a	Th	72	71	3	MMIII/LMI
138	NH	Room 2a	Th	72	71	3	MMIII/LMI
139	NH	Room 2a	Th	61	74	3	MMIII/LMI
140	NH	Room 2a	Th	72	73	3.5	MMIII/LMI
141	NH	Room 2a	Th	72	73	3.5	MMIII/LMI
142	NH	Room 2a	Th	72	73	3.5	MMIII/LMI
143	NH	Room 2a	Th	72	73	3.5	MMIII/LMI
144	NH	Room 2a	DJ	0.79	21	17	MMIII/LMI
145	NH	Room 2a	DJ	0.79	24	17	MMIII/LMI
146	NH	Room 2a	DJ	0.79	22	17	MMIII/LMI
147	NH	Room 2a	DJ	0.79	16	17	MMIII/LMI
148	NH	Room 2a	DJ	79	26	18	MMIII/LMI
149	NH	Room 2a	DJ	79	22	18	MMIII/LMI
150	NH	Room 2a	DJ	72	23	18	MMIII/LMI
151	NH	Room 2a	DJ	72	20	18	MMIII/LMI
152	NH	Room 2a	DJ	72	20	18	MMIII/LMI
153	NH	Room 2a	DJ	72	20	18	MMIII/LMI
154	NH	Room 2a	DJ	72	21	18	MMIII/LMI
155	NH	C 11	CS	51	92	4	MMIII/LMI
156	NH	C 11	CS	51	92	4	MMIII/LMI
157	NH	C 11	CS	45	92	4	MMIII/LMI
158	NH	C 11	CS	51	92	4	MMIII/LMI
159	NH	C 11	CS	58	58	4	MMIII/LMI
160	NH	C 11	CS	34	59	4	MMIII/LMI
161	NH	C 11	CS	35	92	4	MMIII/LMI
162	NH	C 11	CS	46	92	4	MMIII/LMI
163	NH	C 11	CS	46	92	4	MMIII/LMI
164	NH	C 11	CS	46	92	4	MMIII/LMI
165	NH	C 11	CS	13	75	4	MMIII/LMI
166	NH	C 11	CS	23	64	4	MMIII/LMI
167	NH	C 11	CS	19	58	4	MMIII/LMI
168	NH	C 11	CS	45	53	4	MMIII/LMI
169	NH	C 11	CS	18	22	4	MMIII/LMI
170	NH	C 11	CS	21	31	4	MMIII/LMI
171	NH	C 11	CS	19	56	4	MMIII/LMI

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	Site	Location	Function	Height	Width	Length	Date
172	NH	C 11	CS	23	34	4	MMIII/LMI
173	NH	C 11	CS	23	38	4	MMIII/LMI
174	NH	C 11	CS	23	33	4	MMIII/LMI
175	NH	C 11	CS	23	30	4	MMIII/LMI
176	NH	C 11	CS	23	52	4	MMIII/LMI
177	NH	C 11	CS	19	48	4	MMIII/LMI
178	NH	C 11	CS	23	35	4	MMIII/LMI
179	NH	C 11	CS	35	70	4	MMIII/LMI
180	NH	C 11	CS	28	75	4	MMIII/LMI
181	NH	C 11	CS	35	70	4	MMIII/LMI
182	NH	C 11	CS	77	96	4	MMIII/LMI
183	NH	Room 15	BS/T	207	59	25	MMIII/LMI
184	NH	Room 12	Tr	11	72	4	MMIII/LMI
185	NH	Room 12	Tr	86	103	4	MMIII/LMI
186	NH	Room 12	FS				MMIII/LMI
187	NH	Room 12	FS	29	50	4	MMIII/LMI
188	NH	Room 12	FS	25	100	4	MMIII/LMI
189	NH	Room 12	FS	60	22		MMIII/LMI
200	NH	Room 12	FS	62	20		MMIII/LMI
201	NH	Room 12	FS	73	23		MMIII/LMI
202	NH	Room 12	FS	73	45		MMIII/LMI
203	NH	Room 12	FS	74	45		MMIII/LMI
204	NH	Room 12	FS	72	45		MMIII/LMI
205	NH	Room 12	FS	27	65		MMIII/LMI
206	NH	Room 12	FS	86	66		MMIII/LMI
207	NH	Room 12	FS	92	66		MMIII/LMI
208	NH	Room 12	BS\T	95	42	8.5	MMIII/LMI
209	NH	Room 12	BS\T	104	42	8.5	MMIII/LMI
210	NH	Room 12	BS\T	41	41	8.5	MMIII/LMI
211	NH	Room 12	BS\T	105	43	8.5	MMIII/LMI
212	NH	Room 12	BS\S	37	31.5	36	MMIII/LMI
213	NH	Room 12	BS\S	84	31.5	?	MMIII/LMI
214	NH	Room 12	BS\S	35	31.5		MMIII/LMI
215	NH	Room 12	BS\S	35	31.5		MMIII/LMI
216	NH	Room 12	BS\S	74	31.5		MMIII/LMI
217	NH	Room 12	BS\S	34	31.5	32	MMIII/LMI
218	NH	Room 12	BS\Fr	17	4.5		MMIII/LMI
219	NH	Room 12	BS\Fr	20	4.5		MMIII/LMI
220	NH	Room 12	BS\Fr	62	4.5		MMIII/LMI
221	NH	Room 12	BS\Fr	26	7.5		MMIII/LMI
222	NH	Room 12	BS\Fr	68	7.5		MMIII/LMI
223	NH	Room 12	BS\Fr	26	4.5		MMIII/LMI
224	NH	Room 12	BS\Fr	54	7.5		MMIII/LMI
225	NH	Room 12	BS\Fr	64	37	?	MMIII/LMI
226	NH	Corridor 8	FS	70	43	4	MMIII/LMI
227	NH	Corridor 8	FS	70	60	4	MMIII/LMI
228	NH	Corridor 8	FS	73	45	4	MMIII/LMI
229	NH	Corridor 8	FS	45	58	4	MMIII/LMI
230	NH	Corridor 8	FS	25	57	4	MMIII/LMI
231	NH	Room 9	DJ	54	18	18	MMIII/LMI
232	NH	Room 9	Tr	70	54	37	MMIII/LMI
233	NH	Room 9	DJ	54	33		MMIII/LMI
234	NH	Room 9	FS	30	39		MMIII/LMI
235	NH	Room 9	FS	103	20	12	MMIII/LMI
236	NH	Room 9	WS	31	24		MMIII/LMI
237	NH	Room 9	WS	42	23		MMIII/LMI
238	NH	Room 9	BS	42	28	3.5	MMIII/LMI

57	PHAI	R 77	FS	0.93	0.88	x	NP
58	PHAI	R 77	FS	1.15	0.87	x	NP
59	PHAI	R 77	FS	0.94	0.85	x	NP
60	PHAI	R 77	FS	0.95	0.85	x	NP
61	PHAI	R 77	FS	0.92	0.62	x	NP
62	PHAI	R 77	FS	0.84	0.62	x	NP
63	PHAI	R 77	FS	0.7	0.6	x	NP
64	PHAI	R 77	FS	1.15	0.58	x	NP
65	PHAI	R 77	FS			x	NP
66	PHAI	R 77	FS			x	NP
67	PHAI	R 77	FS	0.92	1.51	x	NP
68	PHAI	R 77	FS	0.93	1.51	x	NP
69	PHAI	R 77	FS	1.48	0.9	x	NP
70	PHAI	R 77	FS	0.91	0.9	x	NP
71	PHAI	R 77	FS	0.32	0.88	x	NP
72	PHAI	R 77	FS			x	NP
73	PHAI	R 77	FS			x	NP
74	PHAI	R 77	FS			x	NP
75	PHAI	R 77	FS			x	NP
76	PHAI	R 77	FS	0.89	0.16	x	NP
77	PHAI	R 77	FS			x	NP
78	PHAI	R 77	FS			x	NP
79	PHAI	R 77	FS			x	NP
80	PHAI	R 77	DJ	1	0.28	0.25	NP
81	PHAI	R 77	Thr	0.98	1.25	0.05	NP
82	PHAI	R 77	Thr	0.98	1.26	0.05	NP
83	PHAI	R 77	Thr	1	1.31	0.05	NP
84	PHAI	R 77	Thr	0.98	1.24	0.05	NP
85	PHAI	R 77	DJ	1.01	0.3	0.25	NP
86	PHAI	R 77	DJ	0.99	0.25	0.25	NP
87	PHAI	R 77	DJ	0.99	0.26	0.25	NP
88	PHAI	R 77	DJ	0.99	0.15	0.25	NP
89	PHAI	R 79	Thr	1.16	1.27	0.05	NP
90	PHAI	R 79	FS	5.5	6.3	0.05	NP
91	PHAI	R 79	FS			x	NP
92	PHAI	R 79	FS			x	NP
93	PHAI	R 79	FS			x	NP
94	PHAI	R 79	FS			x	NP
95	PHAI	R 79	FS			x	NP
96	PHAI	R 79	FS			x	NP
97	PHAI	R 79	FS			x	NP
98	PHAI	R 79	FS	1	1.12	x	NP
99	PHAI	R 79	FS			x	NP
100	PHAI	R 79	FS	1.08	1.12	x	NP
101	PHAI	R 79	FS	1.12	1.12	x	NP
102	PHAI	R 79	FS	1.8	1.11	x	NP
103	PHAI	R 79	FS			x	NP
104	PHAI	R 79	FS			x	NP
105	PHAI	R 79	FS			x	NP
106	PHAI	R 79	FS			x	NP
107	PHAI	R 79	FS			x	NP
108	PHAI	R 79	FS			x	NP
109	PHAI	R 79	FS			x	NP
110	PHAI	R 79	FS			x	NP
111	PHAI	R 79	FS			x	NP
112	PHAI	R 79	FS			x	NP
113	PHAI	R 79	FS			x	NP

171	PHAI	R 82	FS	x			NP
172	PHAI	R 82	FS	x			NP
173	PHAI	R 82	FS	x			NP
174	PHAI	R 82	FS	x			NP
175	PHAI	R 82	FS	x			NP
176	PHAI	LB 83	ScS	0.17	0.93	0.5	NP
177	PHAI	LB 83	DJ	0.66	0.15	0.15	NP
178	PHAI	LB 83	DJ	0.66	0.15	0.2	NP
179	PHAI	LB 83	ScS	0.17	0.93	0.5	NP
180	PHAI	LB 83	ScS	0.12	1.12	0.33	NP
181	PHAI	LB 83	ScS	0.12	1.13	0.33	NP
182	PHAI	LB 83	ScS	0.12	1.16	0.33	NP
183	PHAI	LB 83	ScS	0.13	1.1	0.33	NP
184	PHAI	LB 83	ScS	0.13	0.68	0.84	NP
185	PHAI	LB 83	ScS	0.14	0.85	0.35	NP
186	PHAI	LB 83	FS	2.2	2.05	0.05	NP
187	PHAI	LB 83	FS	x			NP
188	PHAI	LB 83	FS	x			NP
189	PHAI	LB 83	FS	x			NP
190	PHAI	LB 83	FS	x			NP
191	PHAI	LB 83	FS	x			NP
192	PHAI	LB 83	FS	x			NP
193	PHAI	LB 83	FS	0.93	0.68	0.04	NP
194	PHAI	LB 83	FS	0.35	0.68	0.04	NP
195	PHAI	LB 83	FS	1.4	1.44	0.04	NP
196	PHAI	LB 83	Thr	0.85	0.65	0.05	NP
197	PHAI	LB 83	DJ	0.1	0.65	0.15	NP
198	PHAI	LB 83	DJ	0.1	0.65	0.16	NP
199	PHAI	LB 83	WR	1.5	2.2	0.03	NP
200	PHAI	LB 83	WR				NP
201	PHAI	LB 83	WR	1.52	1	0.03	NP
202	PHAI	LB 83	Pier	0.44	0.44	0.47	NP
203	PHAI	LB 83	Pier	0.47	0.45	0.45	NP
204	PHAI	LB 83	WR	1.21	1.08	0.03	NP
205	PHAI	LB 83	WR	0.91	1.14	0.03	NP
206	PHAI	LB 83	WR	0.97	0.94	0.03	NP
207	PHAI	LB 83	WR	1.5	1.06	0.03	NP
208	PHAI	LB 83	WR	1.5	0.78	0.03	NP
209	PHAI	LB 83	WR	1.5	1	0.03	NP
210	PHAI	LB 83	WR	1.5	0.98	0.03	NP
211	PHAI	LB 83	Plaster	x	x	x	NP
212	PHAI	LB 83	Plaster	x	x	x	NP
213	PHAI	LB 83	WR	0.92	1.01	0.03	NP
214	PHAI	LB 83	WR	0.92	0.885	0.03	NP
215	PHAI	LB 83	WR	0.92	0.42	0.03	NP
216	PHAI	R 81	WR	0.97	1.01	0.03	NP
217	PHAI	R 81	WR	0.3	1.38	0.03	NP
218	PHAI	R 81	WR	0.32	1.54	0.03	NP
219	PHAI	R 81	WR	0.2	0.11	0.03	NP
220	PHAI	R 81	WR	0.15	0.7	0.03	NP
221	PHAI	R 81	WR	0.72	1.08	0.03	NP
222	PHAI	Sc 76	ScS	0.16	1.76	0.42	NP
223	PHAI	Sc 76	DJ	0.72	0.13	0.22	NP
224	PHAI	Sc 76	DJ	0.73	0.13	0.22	NP
225	PHAI	Sc 76	Thr	1.06	0.74	0.03	NP
226	PHAI	Sc 76	FS	1.14	0.91	0.03	NP
227	PHAI	Sc 76	FS	1.14	0.66	0.03	NP

683	PHAI	Mag	WR	0.6	0.4	0.04	NP
684	PHAI	Mag	WR	0.6	0.95	0.04	NP
685	PHAI	Mag	WR	0.6	1.03	0.04	NP
686	PHAI	Mag	WR	0.6	0.91	0.04	NP
687	PHAI	Mag	WR	0.6	0.85	0.04	NP
688	PHAI	Mag	WR	0.6	1.5	0.04	NP
689	PHAI	R 58	DJ	0.8	0.16	0.2	NP
690	PHAI	Corr 58	DJ	0.8	0.16	0.3	NP
691	PHAI	Corr 58	Pier	0.25	0.6	0.75	NP
692	PHAI	Corr 58	DJ	1.05	0.2	0.25	NP
693	PHAI	Corr 58	DJ	1.05	0.2	0.25	NP
694	PHAI	Corr 58	DJ	1.13	0.2	0.32	NP
695	PHAI	Corr 58	DJ	0.86	0.23	0.4	NP
696	PHAI	Corr 58	DJ	1.13	0.23	0.4	NP
697	PHAI	Corr 58	DJ	1.13	0.2	0.4	NP
698	PHAI	Corr 58	DJ	1.13	0.15	0.4	NP
699	PHAI	Corr 58	DJ	1.06	0.13	0.35	NP
700	PHAI	Corr 58	DJ	0.92	0.15	0.35	NP
701	PHAI	R 59	DJ	0.73	0.15	0.3	NP
702	PHAI	R 59	DJ	0.73	0.15	0.5	NP
703	PHAI	R 59	DJ	1.03	0.15	0.3	NP
704	PHAI	R 42	DJ	1.03	0.15	0.3	NP
705	PHAI	R 42	DJ	1.03	0.15	0.3	NP
706	PHAI	R 42	Thr	0.1	0.7	0.04	NP
707	PHAI	R 44	DJ	0.9	0.15	0.2	NP
708	PHAI	R 44	DJ	0.9	0.15	0.25	NP
709	PHAI	R 43	DJ	0.8	0.15	0.24	NP
710	PHAI	R 43	DJ	0.8	0.23	0.24	NP
711	PHAI	SC 42	ScS	0.125	1.5	0.42	NP
712	PHAI	SC 42	SCS	0.125	1.5	0.42	NP
713	PHAI	SC 42	SCS	0.125	1.5	0.42	NP
714	PHAI	SC 42	SCS	0.125	1.5	0.42	NP
715	PHAI	SC 42	SCS	0.125	1.5	0.42	NP
716	PHAI	SC 42	SCS	0.125	1.5	0.42	NP
717	PHAI	SC 42	SCS	0.125	1.5	0.42	NP
718	PHAI	SC 42	SCS	0.125	1.5	0.42	NP
719	PHAI	SC 42	SCS	0.125	1.5	0.42	NP
720	PHAI	SC 42	SCS	0.125	1.5	0.42	NP
721	PHAI	SC 42	SCS	0.125	1.5	0.42	NP
722	PHAI	R 44	J	0.18	1.03	0.55	NP
723	PHAI	R 44	FS	0.6	1.1	0.05	NP
724	PHAI	R 44	DJ	0.56	0.1	0.14	NP
725	PHAI	R 45	DJ	0.56	0.18	0.25	NP
726	PHAI	R 45	J	0.18	0.58	0.2	NP
727	PHAI	R 45	J	0.18	0.62	0.26	NP
728	PHAI	R 46	J	0.18	0.6	0.36	NP
729	PHAI	R 92	J	0.15	1.2	0.54	NP
730	PHAI	R 92	J	0.15	0.83	0.5	NP
731	PHAI	R 92	DJ	1.05	0.2	0.35	NP
732	PHAI	R 92	DJ	1.1	0.2	0.4	NP
733	PHAI	R 57	DJ	1	0.2	0.24	NP
734	PHAI	R 57	DJ	1	0.2	0.24	NP
735	PHAI	Corr 88	FS	9.4	1.85	0.05	NP
736	PHAI	Sc 88	ScS	1.1	2.5	0.125	NP

	Site	Location	Function	Height	Width	Length	Date
108	AT	R 14	ScS	0.12	0.95	0.33	NP
109	AT	R 14	ScS	0.12	0.95	0.33	NP
110	AT	R 14	ScS	0.12	0.95	0.33	NP
111	AT	R 14	ScS	0.12	0.95	0.33	NP
112	AT	R 14	ScS	0.12	0.95	0.4	NP
113	AT	R 14	ScS	0.12	0.76	0.64	NP
114	AT	R 14	DJ	0.69	0.18	x	NP
115	AT	R 14	DJ	0.7	0.19		NP
116	AT	R 14	DJ	0.65	0.2		NP
117	AT	R 14	DJ	0.68	0.15		NP
118	AT	R 14	DJ	0.67	0.18		NP
119	AT	R 14	DJ	0.75	0.2		NP
120	AT	R 14	DJ	0.74	0.16		NP
121	AT	R 14	Thr	0.72	0.66	x	NP
122	AT	R 14	Thr	0.7	0.45		NP
123	AT	R 14	Thr	0.7	0.7		NP
124	AT	R 14	Thr	0.65	0.72		NP
125	AT	R 14	Thr	0.6	0.6		NP
125a	AT	R 14	WR	0,13+	0.61	0.025	NP
126	AT	R 14	FS	1.32	DR	0.05	NP
127	AT	R 14	FS	0.6	DR	0.05	NP
128	AT	R 14	FS	0.4	DR	0.05	NP
129	AT	R 14	FS	DR	DR	0.05	NP
130	AT	R 13	FS	DR	DR	0.05	NP
131	AT	R 13	FS	DR	DR	0.05	NP
132	AT	R 13	DJ	0.77	0.16	x	NP
133	AT	R 13	DJ	0.77	0.16	x	NP
134	AT	R 13	Thr	0.8	0.74	x	NP
135	AT	R 13	DJ	0.81	0.28		NP
136	AT	R 13	DJ	0.81	0.28		NP
137	AT	R 13	Thr	0.76	0.91		NP
138	AT	R 13	DJ	0.76	0.16		NP
139	AT	R 13	DJ	0.74	0.2		NP
140	AT	R 13	DJ	0.7	0.25		NP
141	AT	R 13	DJ	0.61	0.28		NP
142	AT	R 13	DJ	0.64	0.2		NP
143	AT	R 13	DJ	0.67	0.18		NP
144	AT	R 13	Sfr	0.62	0.08		NP
145	AT	R 13	Sfr	0.44	0.09		NP
146	AT	R 13	Sfr	0.4	0.08		NP
147	AT	R 13	DJ	0.44	0.25		NP
148	AT	R 13	DJ	0.73	0.22		NP
149	AT	R 13	DJ	0.72	0.23		NP
150	AT	R 13	DJ	0.72	0.22		NP
151	AT	R 13	Thr	0.72	0.72		NP
152	AT	R 13	Thr	0.75	0.72		NP
153	AT	R 13	Thr	0.72	0.72		NP
154	AT	R 13	WR	0,4+	1.16		NP
155	AT	R 13	WR	0,23+	1.17		NP
156	AT	R 13	WR	0,56+	1.15		NP
157	AT	R 13	WR	1,30+	0.89		NP
158	AT	R 13	FS	1	1.45	0.35	NP
159	AT	R 13	FS				NP
160	AT	R 13	FS				NP

	Site	Location	Function	Height	Width	Length	Date
430	AT	R 23	BS	0.3	0.28	0,28+	NP
431	AT	R 23	BS	0.3	0.52	0.065	NP
432	AT	R 23	BS	0.3	0.27	0.04	NP
433	AT	R 23	BS	0.3	0.52	0.04	NP
434	AT	R 23	BS	0.3	0.25	0.3	NP
435	AT	R 23	BS	0.055	0.28	0.32	NP
436	AT	R 23	BS	0.055	1.57	0.32	NP
437	AT	R 23	BS	1,02+	0.72	0.32	NP
438	AT	R 23	BS	0,4+	0.45	0.32	NP
439	AT	R 23	BS	0,55+	0.7	0.32	NP
440	AT	R 23	DJ		0.7	0.3	NP
441	AT	R 23	WR	1,12+	0.74		NP
442	AT	R 23	WR	0,45+	0.9		NP
443	AT	R 23	floor size	x			NP
444	AT	R 2	BS	0,28+	0.3	0.04	NP
445	AT	R 2	BS	0,28+	0.57	0.04	NP
446	AT	R 2	BS	0,28+	0.3	0.04	NP
447	AT	R 2	BS	0,28+	0.55	0.04	NP
448	AT	R 2	BS	0,28+	0.32	0.04	NP
449	AT	R 2	BS	0,28+	0.55	0.04	NP
450	AT	R 2	BS	0,28+	0.3	0.04	NP
451	AT	R 2	BS	0,28+	0.55	0.04	NP
452	AT	R 2	BS	0,28+	0.34	0.3	NP
453	AT	R 2	BS	0.57	2.13	0.4	NP
454	AT	R 2	BS	0.57	1.36	0.4	NP
455	AT	R 2	BS	0.57	0.26	0.4	NP
456	AT	R 2	BS	0,58+	0.3	x	NP
457	AT	R 2	BS	1,45+	0.52	x	NP
458	AT	R 2	BS	1,45+	1.15	x	NP
459	AT	R 2	BS	0.87	1.41	x	NP
460	AT	R 2	Pier	0.82	0.7	0.7	NP
461	AT	R 2	ScS	0.15	0.95	0.35	NP
462	AT	R 2	ScS	0.15	0.95	0.35	NP
463	AT	R 2	ScS	0.15	0.95	0.35	NP
464	AT	R 2	Pier	0.82	0.7	0.71	NP
465	AT	R 2	BS	0.3	0.3	0.04	NP
466	AT	R 2	BS	0.3	0.3	0.04	NP
467	AT	R 2	BS	0.3	0.5	0.04	NP
468	AT	R 2	BS	0.3	0.3	0.04	NP
469	AT	R 2	BS	0.37	1.8	0.05	NP
470	AT	R 2	WR	1.1	1,73+	0.04	NP
471	AT	R 2a	BS	0.34	0.32	0.04	NP
472	AT	R 2a	BS	0.34	0.65	0.04	NP
473	AT	R 2a	BS	0.34	0.3	0.04	NP
474	AT	R 2a	BS	0.34	0.67	0.04	NP
475	AT	R 2a	BS	0.34	0.32	0.04	NP
476	AT	R 2a	BS	0.34	0.62	0.04	NP
477	AT	R 2a	BS	0.37	0.3	0.04	NP
478	AT	R 2a	BS	0.37	0.7	0.04	NP
479	AT	R 2a	BS	0.37	],3	0.04	NP
480	AT	R 2a	BS	0.37	0.3	0.04	NP
481	AT	R 2a	BS	0.37	1.04	0.04	NP
482	AT	R 2a	BS	0,35+	1.24	0.04	NP
483	AT	R 2a	BS	0.38	2.5	0.05	NP

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	Site	Location	Function	Height	Width	Length	Date
484	AT	R 2a	BS	0.56	1.88	0.035	NP
485	AT	R 2a	BS	0,42+	0.4	0.055	NP
486	AT	R 2a	BS	0,42+	1.88	0.055	NP
487	AT	R 2a	BS	0,42+	2.5	0.035	NP
488	AT	R 2a	FS	0.9	0.85	0.035	NP
489	AT	R 2a	FS	0.74	0.13	0.7	NP
490	AT	R 2a	Pier	0,42+	0.71	0,42+	NP
491	AT	R 2a	ScS	0.15	1.88	0,42+	NP
492	AT	R 2a	ScS	0.15	1.88	0,42+	NP
493	AT	R 2a	ScS	0.15	1.88	0,42+	NP
494	AT	R 2a	ScS	0.15	1.88	0,42+	NP
495	AT	R 2a	ScS	0.15	1.88	0,42+	NP
496	AT	R 2a	ScS	0.15	1.88	0,42+	NP
497	AT	R 2a	ScS	0.15	1.88	0,42+	NP
498	AT	R 2a	ScS	0.15	1.88	0,42+	NP
499	AT	R 2a	ScS	0.15	1.88	0,42+	NP
500	AT	R 2a	ScS	0.15	1.88	0,42+	NP
501	AT	R 61	Total Vol	0.15			NP

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	Site	Location	Function	Height	Width	Length	Date
767	MY			33	14	7	MMIII/LMIA
768	MY			18	14	5	MMIII/LMIA
769	MY			15	12	5.5	MMIII/LMIA
770	MY			33	20	5	MMIII/LMIA
771	MY	Pile B		32	18	9	MMIII/LMIA
772	MY	Pile A		36	30	4.6	MMIII/LMIA
773	MY	Pile B		7	36	39	MMIII/LMIA
774	MY	Pile B		6	89	39	MMIII/LMIA
775	MY	Pile B		7	53	50	MMIII/LMIA
776	MY	Pile B		3	45	48.5	MMIII/LMIA
777	MY	Pile A	AS	47.5	25	15	MMIII/LMIA
778	MY	Pile A	AS	54	20	30	MMIII/LMIA
779	MY	Pile A	AS	60	29	25	MMIII/LMIA
780	MY	Pile A	AS	25	45	16	MMIII/LMIA
781	MY	Pile A	AS	50	23	25	MMIII/LMIA
782	MY	Pile A	AS	25	30	29	MMIII/LMIA
783	MY	Pile A	AS	24	24	48	MMIII/LMIA
784	MY	Pile A	AS	22	20	30	MMIII/LMIA
785	MY	Pile A	AS	22	35	50	MMIII/LMIA